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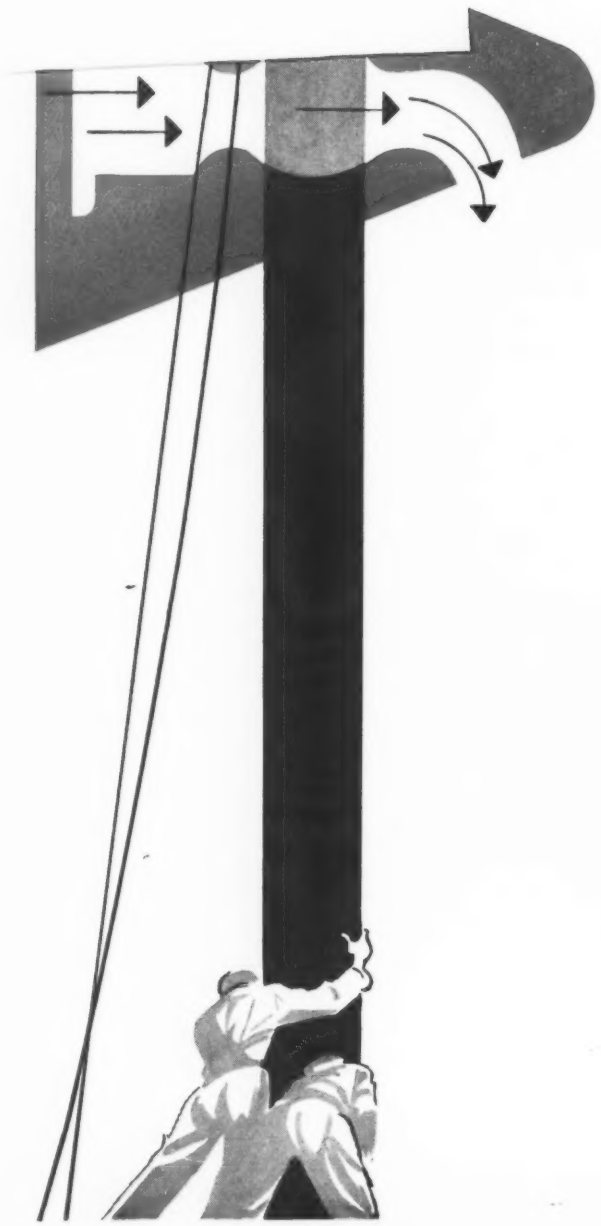

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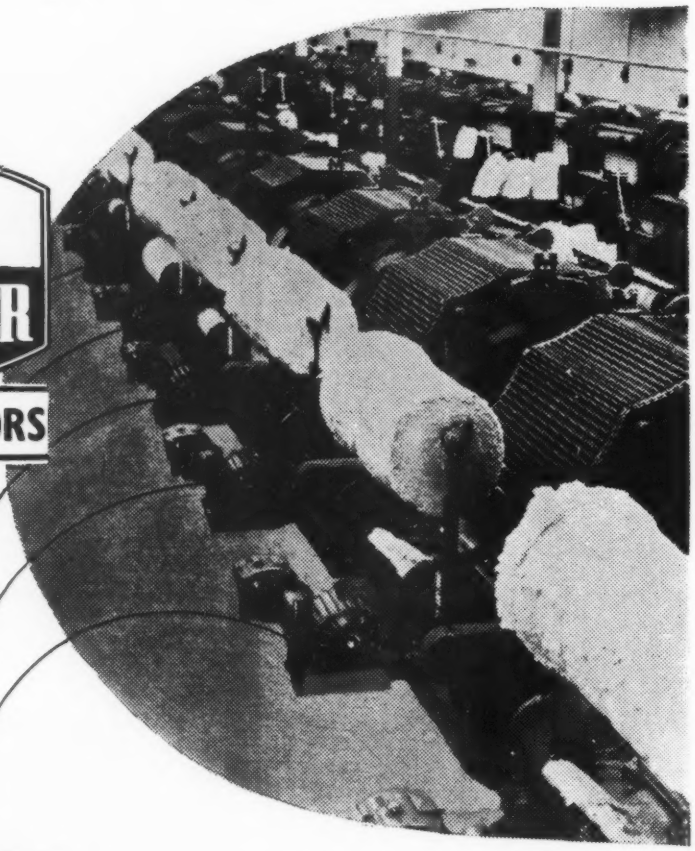

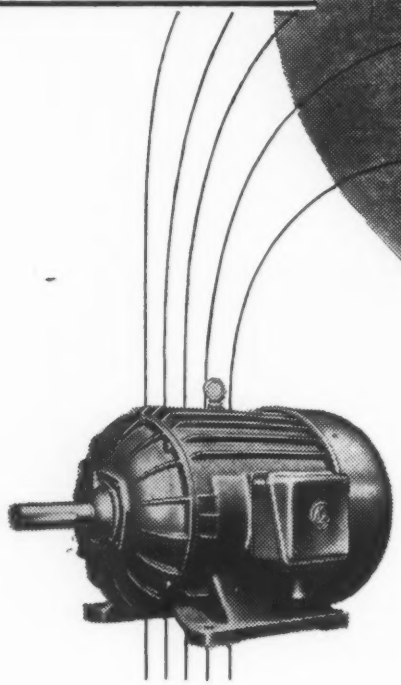

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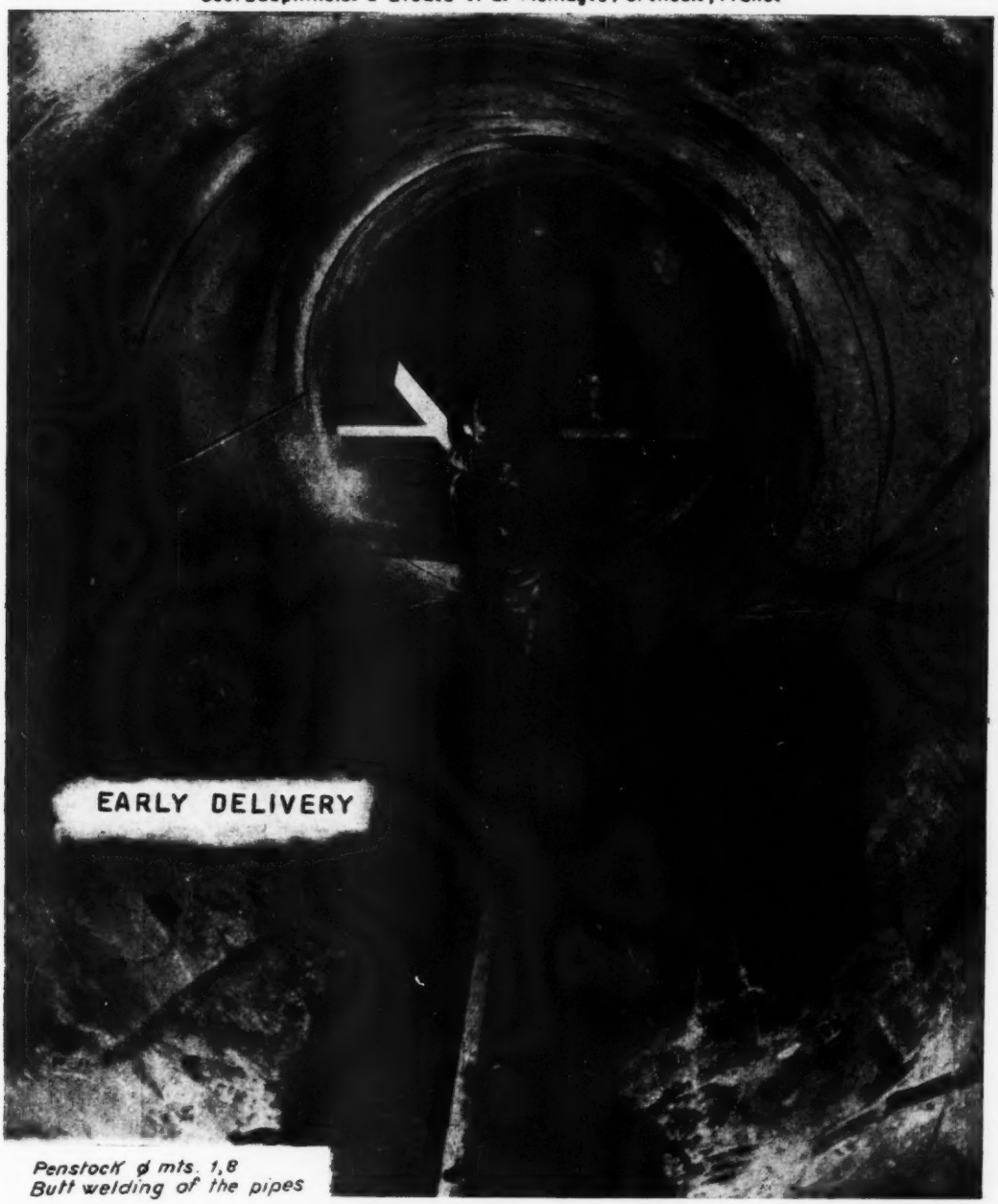

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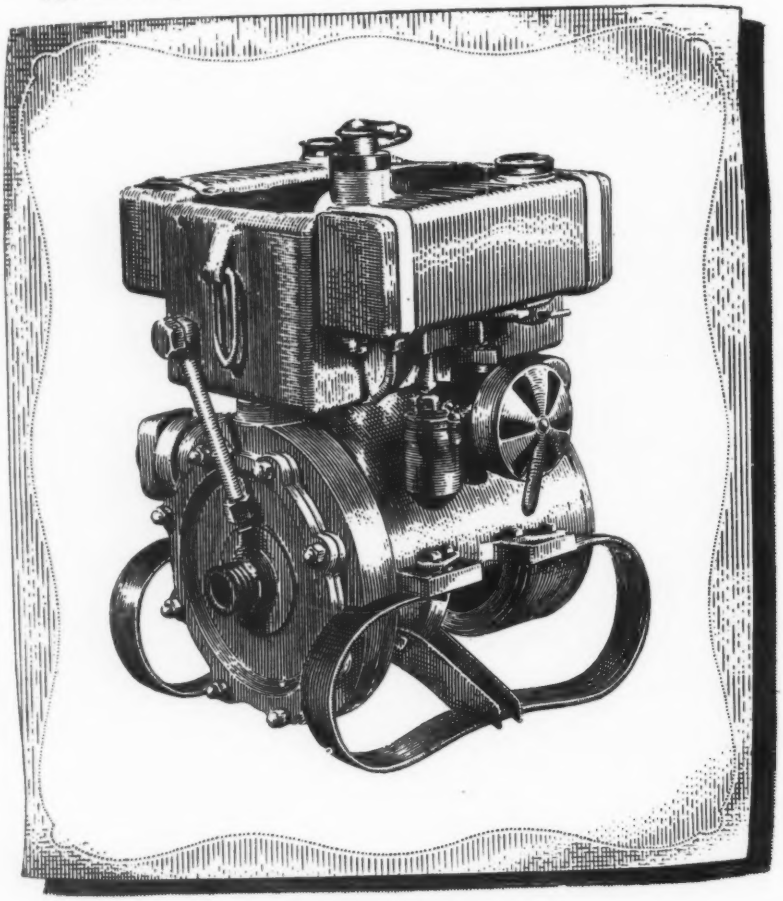

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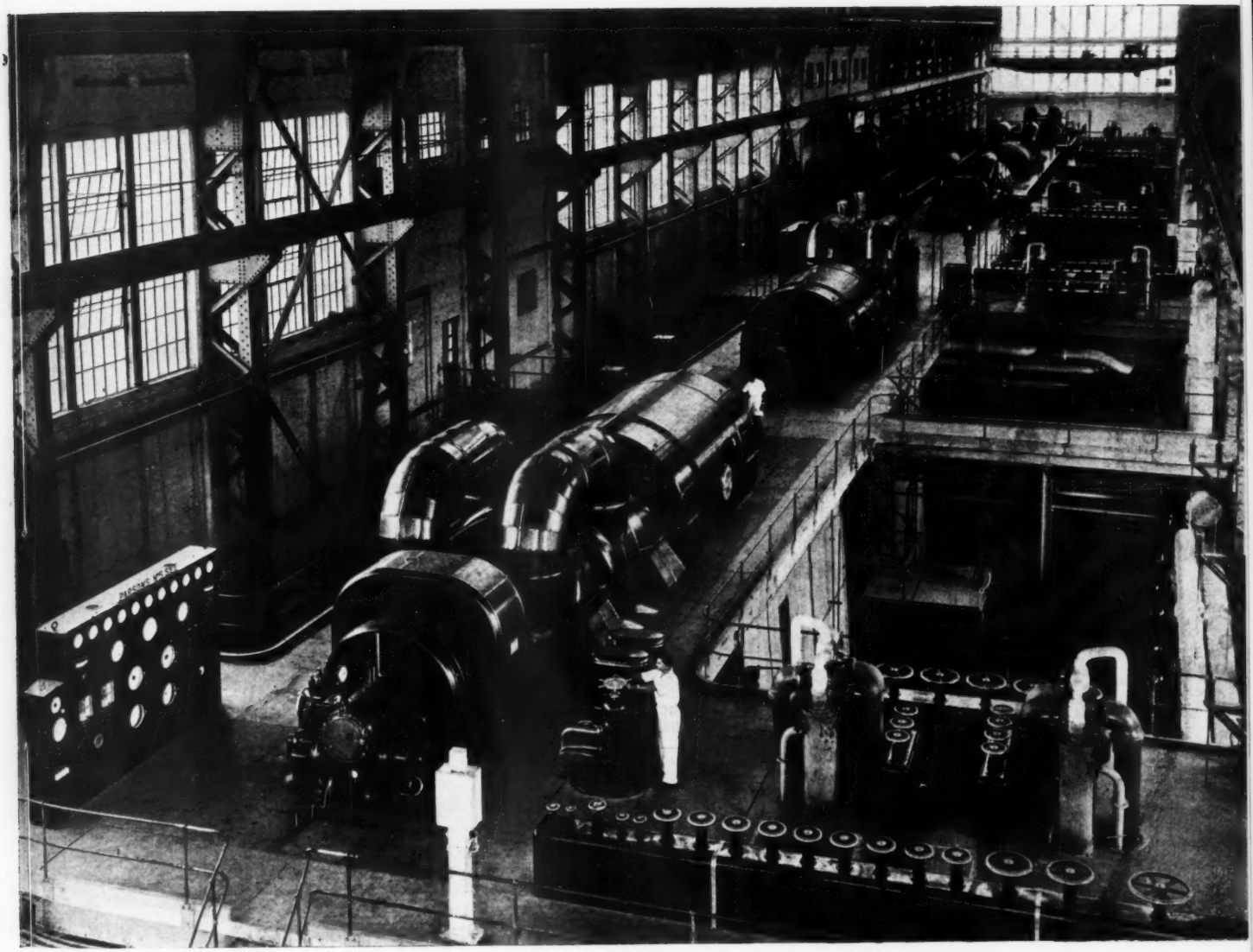

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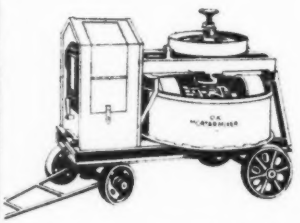

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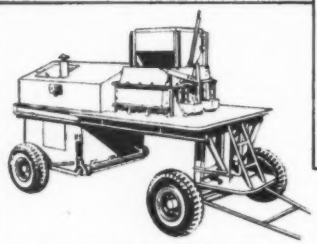

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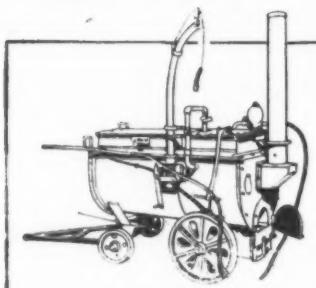

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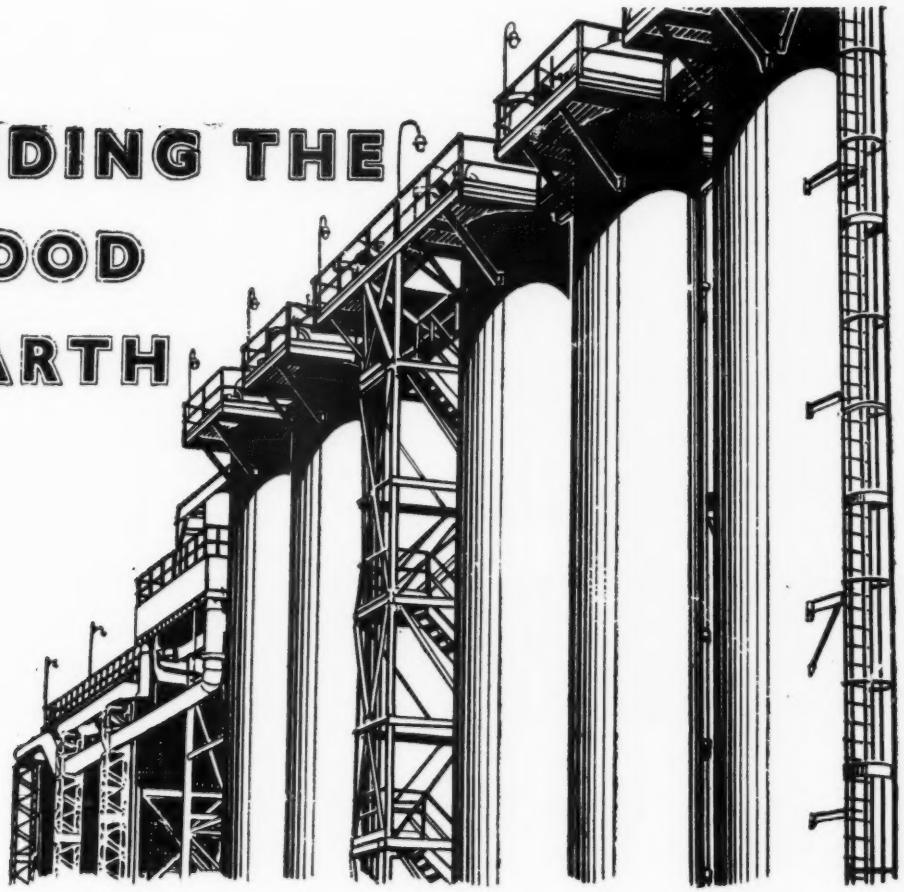

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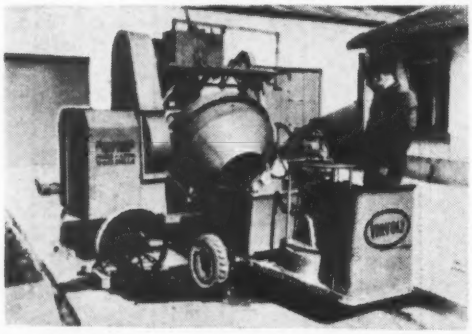

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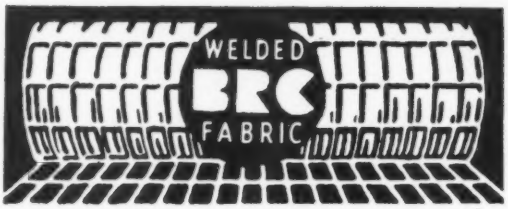

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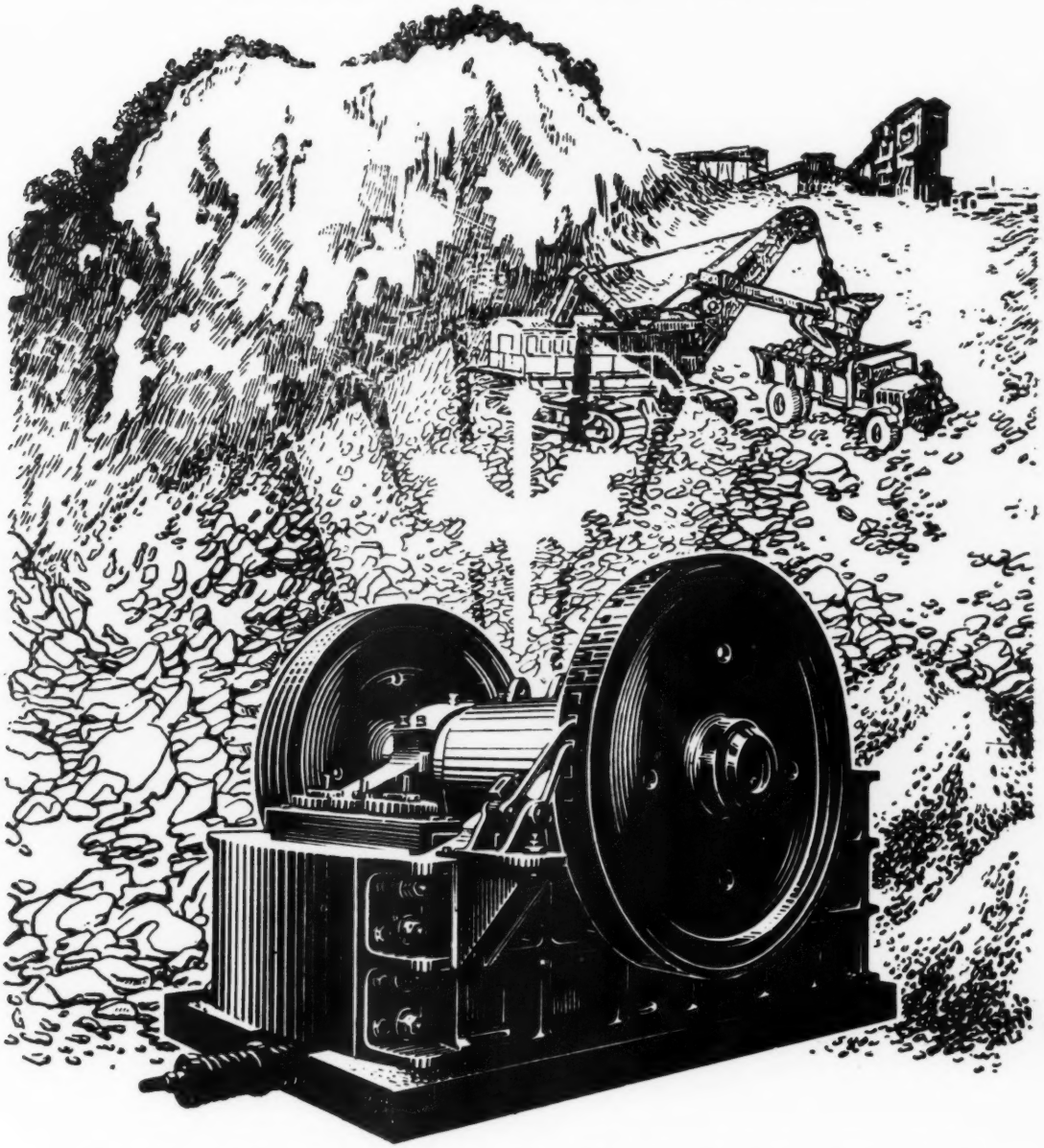

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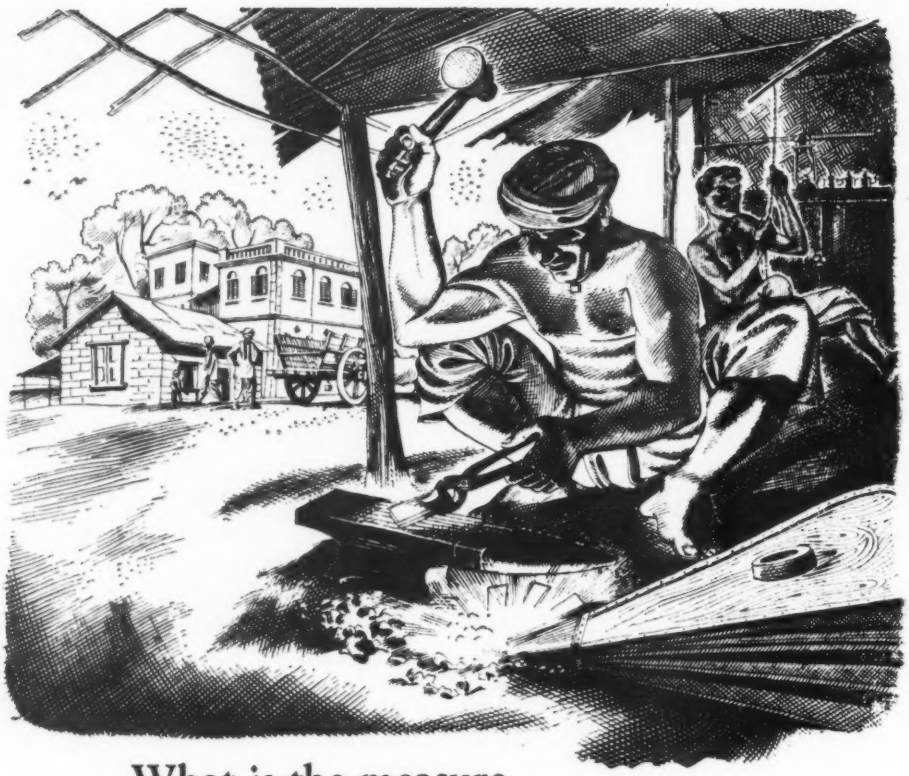

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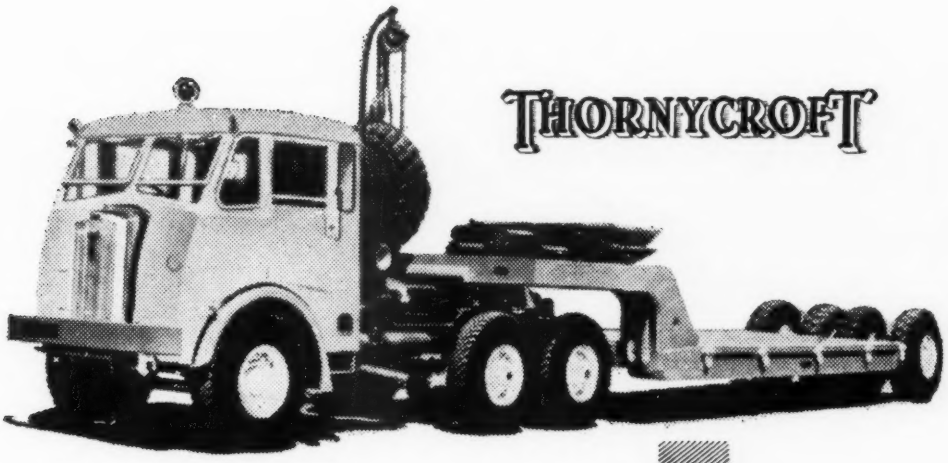

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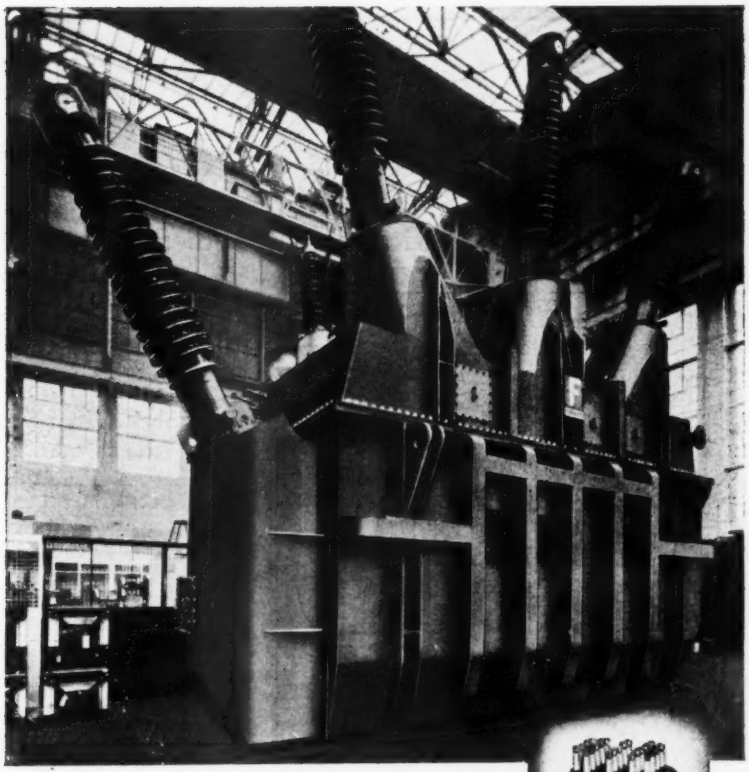

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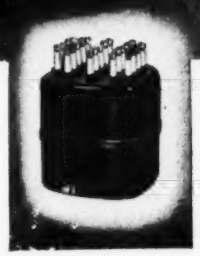

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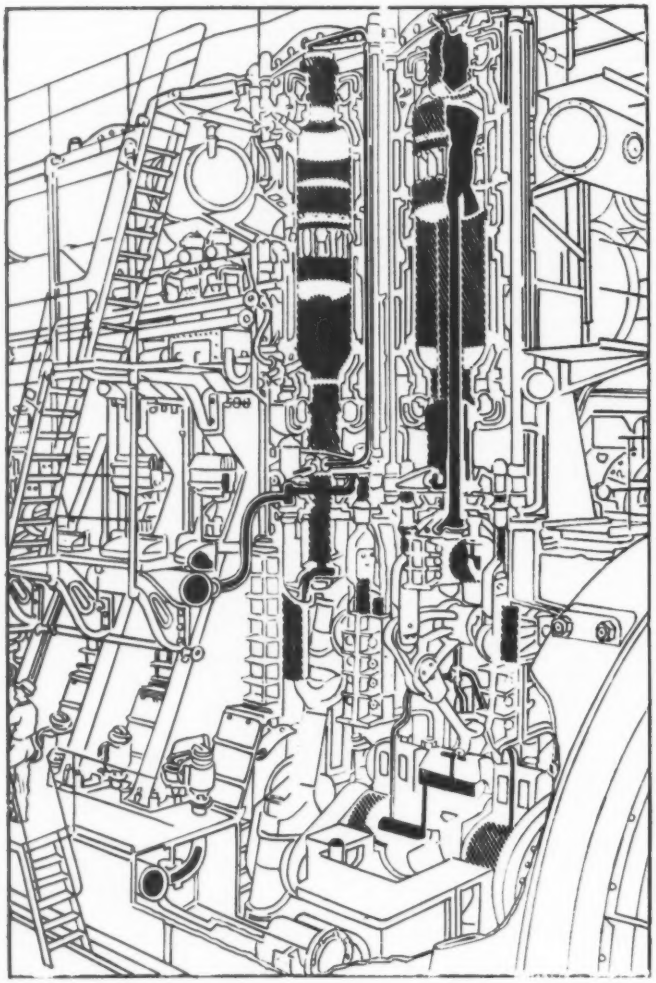

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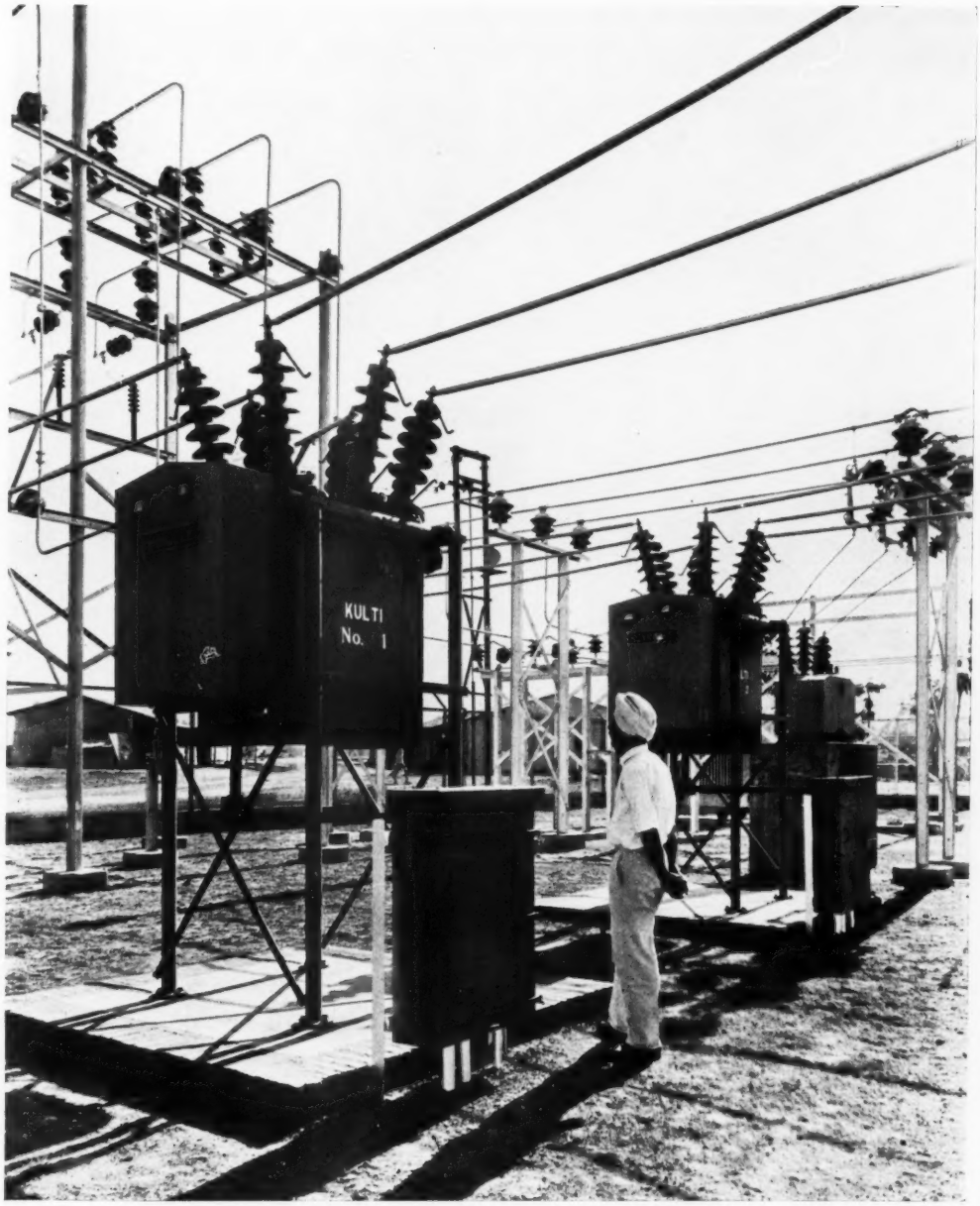

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Editor : **K. K. Sinha** **P. K. Menon** : Mg. Editor

Vol. V **October, 1955** **No. 10**

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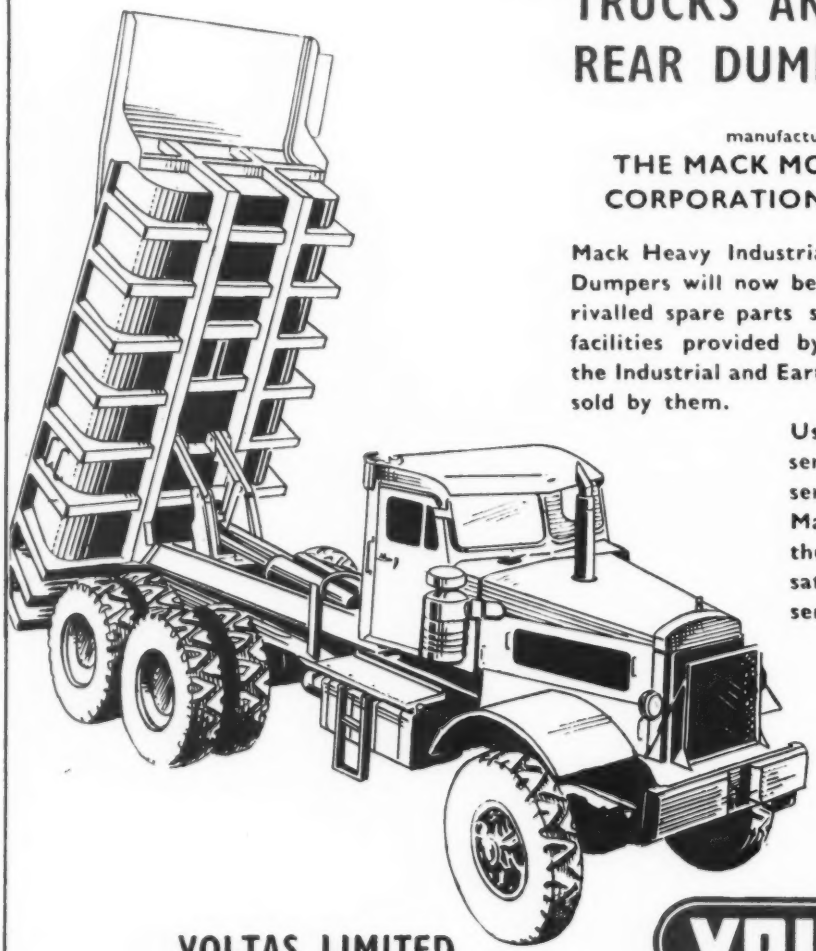

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The Engineer's Contribution to the Conservation of Natural Resources

HAROLD HARTLEY

This first Graham Clark Lecture delivered by the eminent engineer in May 1955 at London is an outstanding document in the literature on engineering. We publish the Lecture in full by special arrangement with the Institution of Civil Engineers under whose auspices the lecture was delivered in the belief that it should be read by all engineers in Asia. The Lecture is an ample proof, if that be needed, that there is an essential unity in the engineering profession although the increasing specialisation in each of its branches tends to create the impression that one is unconnected with the others, thus coming in the way of a wider outlook.

The problem of conservation of natural resource itself is assuming even greater importance as these limited resources are being consumed at a pace unimaginable even fifty years ago. It is a problem of equal importance both to the highly developed as well as the under-developed countries in the world. It is therefore hoped that all engineers will take this opportunity of going through this lecture published here and thus enrich their perspective and widen their outlook.

It is my privilege this afternoon to give the first Graham Clark Lecture and it is appropriate, therefore, that I should begin by paying a tribute to the man whom they commemorate and whose idea they were. I first met Graham Clark when I gave the James Forrest Lecture in 1933 and from then onwards like so many of you I had to thank him for constant acts of kindness and courtesy. The Secretaries of the Institutions, if they are wise, can exert great influence on policy, and this was certainly true of Graham Clark. But apart from all he did for the well-being of his own Institution for 17 years as Secretary, his most important contribution was his insistence on the essential unity of the engineering profession. He saw so clearly that with the inevitable increase of specialization there was an increasing need to secure a common understanding and sympathy, as any great engineering work was bound to be a combined operation. This is an aspect to which I shall return in my lecture more than once. And as a means of fostering this mutual understanding Graham Clark suggested these lectures on subjects of common interest to the three Institutions. As for 15 years it was my happy task to co-ordinate the work of civil, mechanical, electrical, marine, signal and road motor engineers and provide them with a common research service, I share his point of view.

Graham Clark was constantly thinking out means of strengthening the bonds between the Institutions and of forging new links with the engineers of other countries. With the experience of the war he and his colleagues set out to form the Commonwealth body which first met in 1946. A year later, taking advantage of the proposals of the second oldest engineering body in the world—the Royal Dutch Institution—they embarked on the formation of the European and American Conference, when Graham Clark's fluent knowledge of French was of great assistance. Those are some of his constructive contributions which this lecture is meant to keep in mind.

The Scope of the Lecture

When I came to consider the title of this lecture I was faced with a certain dilemma for it is the ingenuity and initiative of the engineer in satisfying the growing demands of the world by new inventions and revolutionizing our way of living, which have stepped up the consumption of natural resources so that the ever-growing inroads upon them have now become a matter of serious concern. In 1828 Thomas Tredgold defined engineering as "the art of directing the sources of power of Nature for the use and convenience of man". That still stands today if for "sources of power" we substitute the word in my title "resources", bearing in mind that since 1828 the profession of engineer has been continuously extended to to include, besides civil engineering, mechanical, electrical and chemical engineering and all the other technologies which today administer to the comfort and well-being of mankind—there is no need to enumerate them. I shall therefore interpret my title in the broadest sense to include all these engineering technologies as it is the intention of these lectures to commemorate the wide outlook of Graham Clark himself and his wish to see the Institutions co-operating on broad lines of policy. How am I to reconcile the idea of conservation with the steadily increasing consumption by the engineer of the world's natural resources?

Now conservation is defined in the Oxford dictionary as "preservation from destructive influences, decay or waste." Leaving aside for the moment the raw materials which are the basis of all engineering production, let me ask what are the natural resources on which civilization has been built and which today are proving the limiting factors both in development and in supplying the world's food, its most crying need? The answer is soil and water. It is here from the earliest times that the engineer has made his basic contribution to the conservation of resources, and the material future of the world is so largely dependent on his continuous success in this field.

Water and the Irrigation Engineer

Water I put first as it is essential to all forms of life and industry. You may remember the words of Robert Browning standing at the window of his palace on the Grand Canal at Venice when a total abstainer was extolling the virtues of water. "Water",

SIR HAROLD HARTLEY, K.C.V.O., F.R.S., *is a British engineer welknown throughout the world.*

said Browning, "as you see, for purposes of locomotion most convenient, for washing indispensable, but to drink, God forbid." Be that as it may, water is proving more and more to be the indispensable resource on which plans so often have to be based and its conservation has the highest priority. Without it soil becomes a desert, production an impossibility but water is also a potent source of destruction and a carrier of disease, so the engineer has here a duel task.

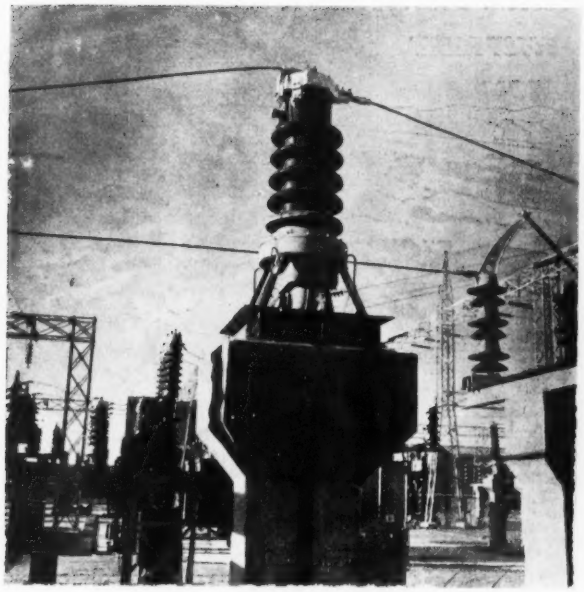
We are dependent for fresh water on rainfall, on lakes, rivers and springs on underground and man-made reservoirs, and for salt water on the sea. Thanks to the sun's radiation there is a continuous cycle of evaporation and rainfall, 98 per cent of the earth's water is in the sea, 98 per cent of the rest is frozen in the polar ice caps, only 0.04 per cent of the water is in the rivers and lakes, and only one part in 100,000 in the hydrologic cycle in the atmosphere on which life depends. The formation of soil is dependent on the weathering action of water and ice on the rocks, some soils are wind-blown but most are formed by waterborne alluvium. That is the raw material on which in prehistoric times the living assemblage which constitutes fertile soil developed, with its vast population of micro-organisms, fungi, algae, protozon and bacteria, of which there are many millions in a gram of soil. Then Nature took a hand in conserving this precious material with her forests on the slopes with their deep roots to absorb and hold the water and protect the soil against the run-off. On the plains, the prairies and pampas of N. and S. America, grass held the soil and gave it permanence. The coming of man, his interference with Nature's conservation, the feeling of the trees and the ploughing of the plains made problems for the engineer to grapple with.

What was his contribution in the oldest centres of civilization? They were not situated in the temperate zone with its kindly rainfall but in the rainless semi-arid zones of Mesopotamia and Egypt and their existence was dependent on the irrigation engineer. It was the early skill of the irrigation engineer that made possible the temples and pyramids of Egypt and the hanging gardens of Babylon. In Egypt irrigation dates from the Old Kingdom, possibly as early as 3000 B.C., when embankments were built partly as a flood protection and partly to form a reservoir. From this developed a system of basin irrigation from the Nile flood with terraced basins all the way from Aswan to the sea. In Mesopotamia the Sumerians fertilized their fields by irrigation trenches as early as 5000 B.C. and there is an inscription recording the irrigation schemes of Hammurabi the founder of the Babylonian Empire in the year 2000 B.C. The fertility of Babylonia became a source of envy and astonishment to the Greeks. Later Sennacherib built a great aqueduct 50 miles long to bring water to Nineveh and to irrigate the orchards and gardens outside the city wall. It was as wide as an arterial road and paved with masonry; a dam with sluice gates regulated the flow and enabled water to be stored. These early irrigation engineers were most skilful in the design and control of their large canal systems. Some like the Narhwan Canal running for 200 miles parallel with the Tigris rivalled the largest modern works in their boldness of conception. They knew how to divert rivers by dams and to dig great artificial canals to lead the river into their irrigation systems and to avoid the risks of erosion and silt.

The great cities like Ur of the Chaldees were dependent on water and when the Euphrates shifted its course and the network of irrigation canals were emptied Ur was abandoned and left to become the impressive heap of ruins we fly over today. Others like Babylon, Nineveh and Ctesiphon were more fortunate and their irrigation systems continued as the basis of their fertility and wealth until the 13th Century when they were destroyed by the Mongol invaders and Mesopotamia became a land of ruins and desolation through which great waters ran to waste or overflowed their banks to make material swamps.

In the Roman Empire water was carried in great aqueducts on arches wherever it was needed, and when an aqueduct had to cross a valley on tiers of arches, like the Pont du Gard at Nimes, their relative positions were structurally correct. I well remember the first time I realized what water meant to man. After a long ride on an obstinate mule through the sandy foothills of the northern range of mountains in Cyprus, we suddenly came over a rise to the village of Kythraea with its beautiful orchards in full bloom. We sat down to eat lunch at a great spring, the source of that fertility and across the plain of the Mesaoria one could trace the abutments of the aqueduct that carried that water to Salamis in the days when St. Paul landed there. The aqueduct has perished and Salamis is a wilderness of wattle.

In India the Mogul Emperors extended the irrigation schemes of their predecessors in the arid plains of the Indus and Ganges but their declining empire was unequal to the maintenance and administration to the complex system and so the canals became choked with silt and fell into disuse until the coming of the British in the XIX century and the rebirth of irrigation engineering. By 1830 the engineers of the East India Company had reopened the old Delhi and Jumna canals in the North and were improving the ancient irrigation works in the Cauvery Delta in the South. Many lessons were learnt of the behaviour of water and the problems of scour and silt, and when the famine of 1832 had intensified the need for more water, Proby Cautley in the North and Arthur Cotton in the South, two great pioneers, were able to embark on the great projects which laid the foundation of modern irrigation engineering. Cautley's 300 mile Ganges Canal with its great Solani aqueduct still ranks as one of the major irrigation schemes of the world. Then followed a long series of hydraulic project all over India which increased greatly the



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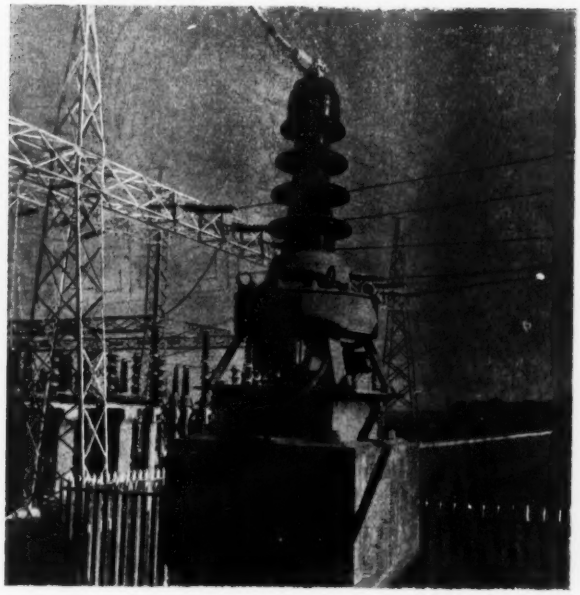
Transformer at Bareilly.



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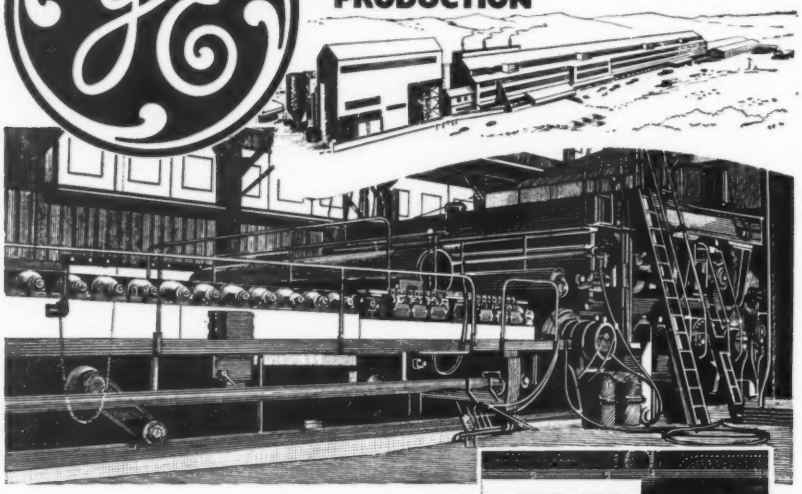

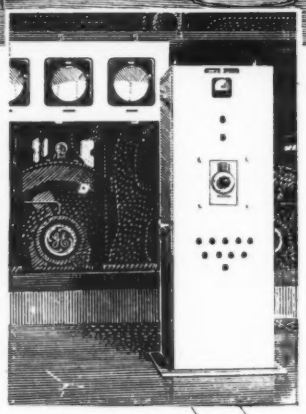

India will soon be able to meet one-third of her requirement of newsprint when the Rs. 6-crore Nepa Mills goes into full production in a few months time. The only one of its kind on the mainland of Asia, six electronic controlled drives of Nepa Mills will turn, abundantly grown *salai* and bamboo of Madhya Pradesh into useful newsprint playing a very important role in the development of the country's press and literacy.

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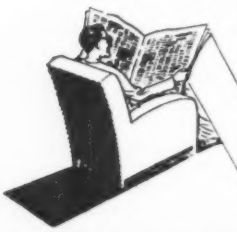

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area of fertile land and provided the experience on which later developments in Egypt and Mesopotamia and other parts of the world were based.

The Multiple Purpose Water Schemes

Meanwhile the advent of hydro-electric power and the advance in engineering techniques made possible the multi-purpose schemes for water control with their objectives of flood control, power supply, irrigation and transport.

The Tennessee Valley with its 27 dams and reservoirs controlling a river basin of 40,000 square miles is one of the most comprehensive of these schemes and has been completed long enough to justify what was claimed for it. The valley has an ample rainfall, so the objectives were flood control, power and communications. The reservoirs provide 11 million acre-feet of storage for flood control at the beginning of the flood season and have saved an immense amount of flood damage each year. Six million acres of rich bottomland is protected in this way. The replanting of the slopes has stopped soil erosion, has made the muddy streams clear again and delayed the silting of the reservoirs. T.V.A. brought new life into a depressed area and did much to raise its standard of living.

The great dams and reservoirs on the American rivers flowing to the West like Grand Coulee, Shasta and the Hoover Dam are more spectacular and serve the additional purpose of the irrigation of millions of acres of rich agricultural land.

In Canada, the Kemano-Kitimat project came into operation last year. In this a string of rivers and lakes has been dammed into a 150-mile reservoir and the flow of the water diverted from east to west. The backed-up water then drops through a 10-mile tunnel in the mountains to the power station at Kemano which has a capacity of 330,000 K.W. This will be increased later to 1.7 million K.W. The power is transmitted 49 miles to Kitimat, where it is used in the aluminium smelter.

Similar schemes with the same objectives are going forward in many other parts of the world. It is interesting that the first major arch dam to be designed by British engineers is on a tributary of the Tigris, the earliest home of irrigation. The Dokan Dam on the Lesser Zab river now under construction will help to control the floods of the Tigris and with a subsidiary barrage will provide irrigation for 2000 sq. miles of desert area. It will have a storage capacity of about 5 million acre-feet and a hydro-electric power potential of 143,000 K.W.

In Africa there are the Volta River and the Shire Valley projects. On the Volta River there are no substantial falls to facilitate the production of hydro-electric power, so the scheme takes the form of a large rockfill dam over 300 ft. high across the river at Ajena which would impound an artificial lake of some 3,000 square miles in area and 300 miles in length. The head is entirely that produced by the dam itself and the power station would provide an average output of 580,000 K.W. continuous. The power would be transmitted to a smelter downstream where it is planned to produce some 210,000 tons of aluminium ingot per annum. The scheme would provide power for other parts of the country, inland navigation on the lake, and irrigation water for at least 200,000 acres of fertile land on the Accra Plains.

The Report on the Shire River Project, which has just been published by the Nyasaland Government, describes a most interesting multi-purpose scheme. It provides for control of Lake Nyasa and the Shire River by a seasonal bund on the river south of the lake, and a series of hydro-electric and flood control schemes lower down the river with a peak capacity of 360,000 K.W. The control of the river would enable large areas of marsh land to be drained, and other promising areas to be irrigated. The reclaimed land could be used for the intensive cultivation of cash crops such as rice and the provision of power would encourage local industries. The scheme would open up a vast inland water transport system where transport is badly needed and it would do much to raise the standard of living and productivity.

Another good example of the engineer's contribution to conservation is the Snowy River Scheme in Australia. The Snowy River, rising on the eastern slopes of the Snowy Mountains, flows southward through country with an adequate rainfall for agriculture and wastes its great flow of water in the sea. On the Western slopes of the Snowy Mountains there rise the streams that unite to form the Murray River which flows through hundreds of miles of arid plains before reaching the sea in South Australia. By building dams in the mountains great volumes of water will be impounded, one reservoir will store seven times the volume of water in Sydney Harbour, and then this water will be diverted by tunnels through the mountains to feed the Murray River system with two million acre-feet per year of irrigation water, which in its flow through 17 power stations will give them a generating capacity of 3 million kilowatts. The first power station is nearly finished and this great scheme when completed will provide Australia with two of her greatest needs for development, power and water, for she is one of the driest countries in the world.

It would be easy to multiply examples, just one more occurs to me that I have seen to show what the engineer can contribute in the remote districts of the world. The Warsak dam and power station on the Kabul River in the N.W. Province of Pakistan, now under construction, will provide 68,000 kilowatts of power and will irrigate 60,000 acres adjoining the arid mountainous country to the Khyber Pass. It will offer a new kind of existence to those wild frontier tribes, the Afridis and Mohmands.

Silt

There is another side to the picture. With the speed with which man is now changing his own environment he is apt to forget that the slow evolution of nature herself is still proceeding. The forces that smoothed the profile of our planet and produced the soil from rocks are still in action. Thousands of millions of tons of rock particles and eroded soils pass down the rivers each year, especially in flood seasons, as the carrying capacity of moving water varies the sixth power of its velocity. That is the main anxiety of the dam builder for the future and he is faced with the dilemma that the more he uses a reservoir for flood control the shorter will be its life. In 200 years the great Lake Mead above the Hoover Dam will be an alluvial plain, and the lives of many reservoirs can be reckoned at a century or less. The Aswan Dam stands out for special reasons as almost unchanging.

Here the engineer becomes an agronomist as forestation, ground cover and terracing can go far to prevent soil erosion and muddy streams. Subsidiary silt catchments can be built upstream but their life is limited. The problem of the deposit of silt in the reservoirs when the stream velocity is diminished is being studied and the persistence of a stream of denser water loaded with mineral particles along the bottom of the reservoir raised hopes that by opening sluices at the bottom of the dam in flood time the deposit will be reduced, but their scouring action is very local. Silt is the great problem of the future for the hydraulic engineer, as with the loss of storage capacity the output of the power station will become more and more dependent on the seasonal flow and more serious still will be the loss of perennial irrigation where it is dependent on storage. The ultimate solution may be new high dams, but the best sites have already been chosen.

Improved Techniques

Let me now turn for a moment to the improved techniques the engineer has evolved in methods of surveying, dam construction and model studies which have helped so much in the quick development of these bold hydraulic projects.

Surveys

Their first requirement is an accurate survey and flying has revolutionized the methods of large scale surveying as by means of aerial photography with stereoscopic cameras to trace the contour lines the preliminary work of mapping new schemes can be done with great speed and accuracy of detail. The nature of the rock and soil, soil erosion, forest cover and changes in the flow of rivers can be surveyed over wide areas with a completeness that was formerly impossible. For instance, 30,000 square miles of country were mapped in connection with the Kariba and Kafue hydro-electric schemes on the Zambesi and 16,000 square miles for the Volta River scheme in the Gold Coast.

Again in these great schemes an accurate knowledge of the form of the underlying strata is an essential preliminary to engineering design. Modern geophysical methods enable this to be determined with great savings of time and effort. The measurement of the time taken by seismic waves, set up by an explosion, to travel directly or after refraction through the underlying rock enables the depth of the bedrock at various points to be determined with an accuracy of 10 per cent. This method was used in the survey of the 300 yard wide rocky gorge of the Kabul River for the Warsak scheme and it saved a large amount of difficult drilling.

The electrical resistance of soil and sub-soil depends largely on its moisture content and it varies from rock to rock, so resistance measurements between different points is another means of determining underground conditions and the existence and depth of a water table. This method was used in the survey of the dam site in the Kariba Gorge on the Zambesi.

These are two examples of the progress that is being made in the application of geophysical methods in engineering which together with the new science of soil mechanics have contributed so much to the rapid design of these large multi-purpose water schemes.

Dam Design and Construction

The progress of concrete design and construction replacing the masonry dams of earlier times has given us the simplicity and grace of the great structures which are adding so quickly to the number of vast reservoirs in the world. This advance has come partly from the scientific analysis of the stresses in the structure, partly from the experience gained in methods of rapid construction by the diversion of water and boring of great rock tunnels, partly from the progress in our knowledge of the properties of concrete and partly from the improved mechanical methods of making and placement of the concrete which in the Grand Coulee Dam reached 20,000 tons of concrete a day. Then there are the methods of diminishing the heat rise during setting by the use of low heat cements and the admixture of pulverized fuel ash, a pozzolanic material, and the removal of the heat developed by refrigeration or circulating water and also the "case-hardening" of the outer surface of the concrete on the spill-way sectors by vacuum application to remove air bubbles and water. The organisation of these projects, the selection and transport of materials, the co-operation of civil, mechanical and electrical engineers constitute a combined operation of great magnitude, and its success in so many parts of the world is a triumph for the engineer.

Hydraulic Models

These great engineering works involve an interference with nature and experience has taught us that whenever one interferes with nature we must watch her reactions very closely with all the help

that science can give. In no field is this more important than in interference with the flow of water. Changes of conditions brought about by new engineering works in a river channel, in a harbour or in coast defences may produce most unexpected results, and the number of independent variables involved is usually too great for a theoretical prediction. Luckily the technique of using scale models in which the effects of changed conditions can be speeded up a thousandfold is now sufficiently advanced to enable a fairly accurate forecast to be made if the model is well planned and its limitations clearly recognised. No model can reproduce in detail all the conditions of the original, for instance the size of the bed material in moving bed models cannot be scaled down to correspond with the other dimensions, and corrections have to be made when the similitude is imperfect. There is thus a limit to what can be expected of a a model and great experience is needed in its use. However the justification of the use of models has been established in many cases by a comparison of their results with those found subsequently when the work has been carried out. The model enables a comparison to be made of various engineering solutions of a problem and thus enables the most economical design to be adopted. The cost of the model is a very small fraction of the total sum involved.

Theoretical studies are also of importance for future developments, for instance Hawthorne's analysis of the secondary flow around struts. Experiments in a hydraulic channel showed that the scouring of the beds of rivers near obstacles may be attributed to secondary flow and that the scouring is less marked with a bicusped than with an elliptical profile.

The first experiments with loose boundary models were carried out by Osborne Reynolds in 1885 in connection with proposals for improving the approaches of the Mersey. He showed that such models, even if they were very small, with a horizontal scale of 1 : 10,600 and a vertical scale of 1 : 396, roughly reproduced what was happening in the estuary. Later his techniques were developed by Gibson for river and estuary flow and drift.

Subsequently, many model laboratories were established on the continent especially in Germany, and from 1929 the Vicksburg experimental station and several other stations were started in the U.S.A. The Delft Station dates from 1933, and Grenoble came into the model field in 1940. In 1919 experiments carried out at Poona by Claude Inglis with loose boundary models of various sizes showed that the changes which occur in nature can only be reproduced in very large scale models, and since then large numbers of such models have been constructed in India, and now, at long last, we have our own Hydraulics Station at Wallingford. Model studies now almost invariably a condition of the contract for major hydraulic works and consequently the provision of adequate facilities at the Wallingford Station are a matter of serious concern in the overseas contracts on which the trade balance of the United Kingdom is increasingly dependent.

Irrigation and its Problems

The present land area in the world cultivated for food is about 1,620 million acres and of this 230 million acres are under irrigation, much of it perennial, and these acres are of special value as they grow more than one crop a year under semi-tropical conditions. It may be possible to double this irrigated area in places where water is the limiting factor in cultivation, as in India, for example, where only six per cent of the river flow is used in this way. Spraying is a much more efficient use of water than surface distribution as it can be controlled and the right amount of water applied when it is most needed. Much progress has been made with spraying in Arizona where water is precious and where the cost of the equipment is outweighed by the increased crop yields.

But irrigation is another interference with nature and the engineer's task is not finished when he has provided the irrigation water, since it brings with it the danger of salinity and alkaline soils which is now threatening large areas in the Punjab. All irrigation water contains some salt which is also present in the soil and unless there is efficient natural or artificial drainage the salt will accumulate and the soils may become alkaline with the loss of soil structure. In Egypt, where there is perennial irrigation, drainage canal carry off the surplus water, and standing in a cotton field in the Delta I have seen salt crystals growing in the drainage canal ten feet below the surface, so small is the margin of safety. The salt water from the drainage canals is finally lifted into the Mediterranean. In the Punjab 500 miles from the sea conditions are much more difficult. More water, either from canals or tube wells, is needed to leach the salt from the soil but some system of drainage and disposal of the drainage water on derelict land seems inevitable and represents a problem for the engineer. The same difficulty arose in the irrigated lands of Arizona and was solved by drainage schemes, and it will recur wherever irrigation is installed without precautions.

The Yangtse river in China provides, I am told, an example of a special type of irrigation which has been in existence for 2,000 years. Water is drawn off at favourable points into irrigation canals and distributed to the land and the drainage water is returned to the river, in which the volume of flow is sufficient to render the added salinity innocuous. The advantage of this method, when the lie of the land permits it and the steady flow of water in the main stream is sufficiently great, is its permanence. It illustrates too the important principle of not attempting to use irrigation water for a larger area than all the attendant circumstances justify.

Irrigation remains a complex problem. Pumping from tube-wells under suitable underground water

conditions may help to solve it, but before reliance can be placed on this a survey of the underground water resources and their quality is essential, and a careful watch must be kept to see that they are not depleted. There is too a risk of changing quality as in the United Provinces when after six years the water from the wells became brackish and useless. Water is so precious that this method should only be regarded as a second line of defence where it is possible to impound water from the maximum flow of rivers, as for example the Indus by engineering works in the Himalayas that would provide both perennial irrigation for great areas, power supplies and diminish the risk of floods and soil erosion.

We need to know much more about the movement of water in the soil, much more about the underground water resources and much more about the possibilities of these multi-purpose water schemes which utilize the world's limited supply of fresh water to the best advantage.

The Future of Water Supplies

So far I have dealt mainly with water in relation to agriculture and there is the wider question of our ability to supply the rapidly increasing consumption of water in the cities and by industry. In some places water is becoming the limiting factor to development and in Britain it is already difficult to locate a new industry needing much clean water or to find inland sites with cooling water for power stations and industry. Nuclear power stations will almost certainly be sited on the coast for this reason. The amounts required by modern industry are large—a million gallons to make a ton of viscose yarn, and 400,000 gallons a ton of steel. Here the engineer can help by the efficient treatment of effluents and sewage, by the reuse of water by means of cooling towers, or by returning well water used for cooling to the strata from which it was drawn. Even in Britain water is needed for irrigation south of a line from the Severn to the Humber if maximum crop yields are to be obtained.

In the United States the threat of water shortage has directed much attention recently to the problem. The Conservation Foundation has directed its main efforts into this field, and five major studies* have recently been published dealing with various aspects. Statistics show that 78 per cent of the precipitation in the U.S.A. is returned to the atmosphere by evaporation or transpiration through plant leaves, leaving 28 per cent to reach the sea by rivers. Some 25 per cent of the water demand is drawn from underground reservoirs, and in many places the water table is falling so that both on the eastern and western seaboard salt water is seeping in from the sea and damaging vegetation. One study on the conservation of ground waters shows the need for much closer knowledge of the underground reservoirs and the movement of ground water to replenish them, in order to regulate their use.

Although the overall resources in the U.S.A. are sufficient it is clear that their effective utilization will be a serious factor in future planning, to which surveys of climate and water flow are an essential preliminary.

Another study examines the prospect of getting water from the sea by various means, freezing, distillation and electrolysis and the prospects seem to be most favourable for the purification of water by electrolysis between ion exchange membranes. In large units the cost may be reduced to two shillings per 1,000 gallons provided that a large sum is is spent on developments.

The effort devoted to these studies shows the urgency of the problem and water conservation is one of the most serious problems for the engineer in other countries besides the U.S.A.

(*to be continued*)

*The Contsevation of Ground Water by Harold E. Thomas, McGraw-Hill, July 1951.
Water In Industry by The Conservation Foundation and The National Association of Manufacturers, December 1950.
Vegetation And Watershed Management by E. A. Colman, The Ronald Press Company, New York, December 1953.
Fresh Water From The Ocean, by Cecil B. Ellis, The Ronald Press Company, New York, January 1954.
The Flood Control Controversy by Luna B. Leopold, and Thomas Maddock, Jr., The Ronald Press Company, New York, May 1954.

Development Resources Corporation

Lazard Freres & Co. and David E. Lilienthal announce the formation of the Development and Resources Corporation with offices at 44 Wall Street, New York City.

Mr. Lilienthal formerly Chairman of T.V.A. and first Chairman of the U.S. Atomic Energy Commission, is Chairman and the Chief Executive Officer of the new company. Mr. Lilienthal is Chairman of the Executive Committee of Minerals & Chemicals Corporation of America and acts as industrial consultant to various companies.

Mr. Gordon R. Clapp, who succeeded Mr. Lilienthal as Chairman of the T.V.A. has resigned as Deputy Administrator of New York City to become President of Development and Resources Corporation.

The Board of Directors include Mr. Lilienthal, Mr. Clapp and two nominees of Lazard Freres & Co.

Development and Resources Corporation has been formed to provide organisational technical and financial guidance in the development of natural resources outside the United States of America. The services of the Corporation will be available not only be advise and assist governmental agencies in the coordination of public programs of river and land development but also in selected private industrial and commercial enterprises. The scope of the Corporation's services will include counsel in production of energy from all sources including atomic energy, when economically feasible. It will also include guidance in projects of modernising agriculture, increasing food supply and improving transport by highway and water.

Studies in the Diversion of Sutlej River at Nangal Dam by means of Models and a Comparison of the Model Results with Prototype Observations

Dr. H. L. UPPAL, M.Sc., Ph.D., F.N.I.,
Director, Irrigation & Power Research Institute, Punjab (India)

T. D. GULATI, M.Sc.,
and
B. D. SHARMA, B.Sc.
Irrigation & Power Research Institute, Punjab (India)

H. L. UPPAL

The Nangal Dam is situated eight miles downstream of Bhakra on the Sutlej River. The banks are composed of hard conglomerate. River is confined within rigid banks 1,000 feet apart. The bed is composed of shingle and boulders. There is a conglomerate and rock in the bed also at certain places. The minimum winter discharge is 3,000 cusecs, while the maximum flood discharge is 3,50,000 cusecs. A diversion dam 86 feet high was proposed to be constructed across the river, capable of ponding upto R.L. 1154.00. This would divert the Sutlej water into the Nangal Hydel Canal and therefrom to the Bhakra Canal System. The high flood level at Nangal experienced in the past was R.L. 1136. The dam was to head up water by 18 feet.

Special Feature

The river is narrow and deep. Due to its limited width and high discharge, the entire available width of the river was to be occupied by the dam. Contrary to the normal practice of constructing the headworks in dry on one side of the the main stream and later diverting the river on to the works, adopted in the Punjab it was decided to construct the dam in two parts. The left side being comparatively high and also dry during winter, the construction was undertaken on the left side first. After the completion of the nine bays on the left side, the river was to be diverted from the right to the left half.

Statement of Problems

After the completion of half of the dam, the river was to be diverted on to it and during the monsoon season the whole of the flood discharge was required to be passed over the half portion of the dam. The inner and the outer ring bunds were to be designed such that these should be along a sound alignment as not to be eroded and also of such a height as not to be overtopped. The rate of development of the cuts and the possibility of scouring of the bed shoals in front of the dam influenced the design of these bunds. These points were required to the determined accurately. To obtain this information, model tests were carried out.

Studies Made

The following studies were made on the model.

Study No. I

An examination of the conditions of river flow with low winter discharge (4,000 cusecs) diverted through the cut.

Study No. II

Effect of connecting the upstream left cut with the right on the downstream side.

Study No. III

Realigning the cut on the basis of Study No. II and an examination of its behaviour in high discharges.

Study No. IV

Determination of river levels with the high bed of XY cut linking to the right side.

Study No. V

Determination of the flow conditions and the likely river levels if only 9 bays on the left could be ready.

Study No. VI

Investigation of measures to relieve excessive discharge intensity in the 9 completed bays of the left half.

Planning and Construction of the Model

Since the diversion was to be done in the lowest river stages in winter corresponding to 4,000 cusecs discharge, the study was made on a large scale model. A geometrically similar model was constructed to the following scales :—

Horizontal scale—Model to Prototy : 16	
Vertical scale—Model to prototype 1 : 16	
Discharge scale 1 : 1024	
Area under the model	25,200 sq ft.
Discharge used	
Corresponding the high flood	342 cusecs

This is one of the largest model investigated at the Station. The composition of the river bed on the prototype varied from sand to conglomerate and its accurate reproduction created certain limitations on the model. However, the bed was moulded with 1/4 to 1/8″ grit with 40% sand and making the portions shown as conglomerate non-erodable. The banks were also made rigid where conglomerate banks were reported to have existed. A complete model representing 9 bays of the dam, the river up and downstream of the dam, canal regulator and 8000 ft. length of the canal was constructed. The crest of the dam in the 9 bays of the left half was constructed to R.L. 1100 only as the diversion was to be done at that level. The bed was moulded according to the latest survey.

Borings showing the nature of the strata below the dam were available for groups of four bays. The strata on the model was also reproduced accurately according to the boring pattern. Pressure pipes were also installed in bays 4 and 5. Jack piers, main piers and dummy piers were reproduced in detail. The barrage gates were all provided with screw lifting arrangement. The canal regulator was placed at an angle of 102.5 to the axis of the dam and the forebays, the breast wall, the piers and gates were all accurately reproduced. The conglomerate bed existing in continuation of the forebay was also reproduced in non-erodable material. A view of the completed model is given in Fig. 1.

Operation of the Model

The cut was made according to the alignment shown in Fig. 2. A diversion bund was also constructed on the right side with top R.L. at 1,115 to start with. Ten gauges were installed on the model. The location of the gauges is shown in Fig. 2. Fig. 2 is printed separately.

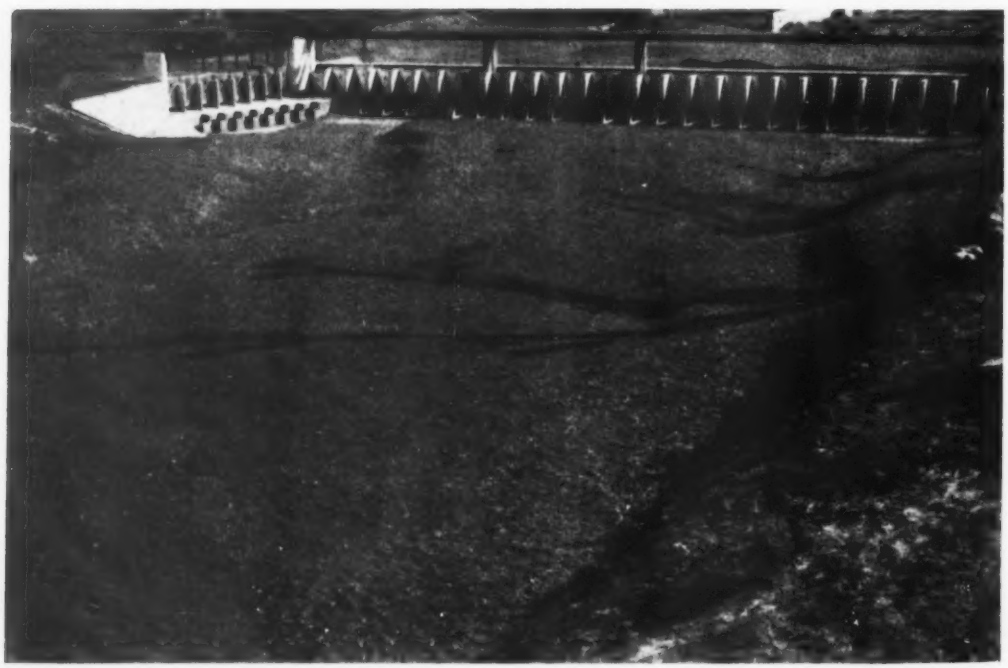
The experiments were started with low river stages and all the different stages of medium, normal and high were examined.

Study No. 1 : Conditions of flow with low winter discharge (4,000 cusecs) diverted through the cut

Low winter stage—(4,000 cusecs discharge). The discharge was allowed to run in the cut for eight hours and all the necessary observations were taken. No development of the cut took place and no change in the sucessive gauge observations occurred. The calculated waters levels are compared with the observed water levels in the table given below :—

R.D.	*Assumed water levels*	*Water levels obtained on the model*
0	R.L. 1108.3	R.L. 1110.7
700	,, —	,, 1109.6
1350	,, 1107.0	,, 1107.6
1500	,, 1106.6	,, 1107.4
1800	,, 1106.6	—
2100	—	,, 1106.9

Fig. 1.— A view of the completed model.



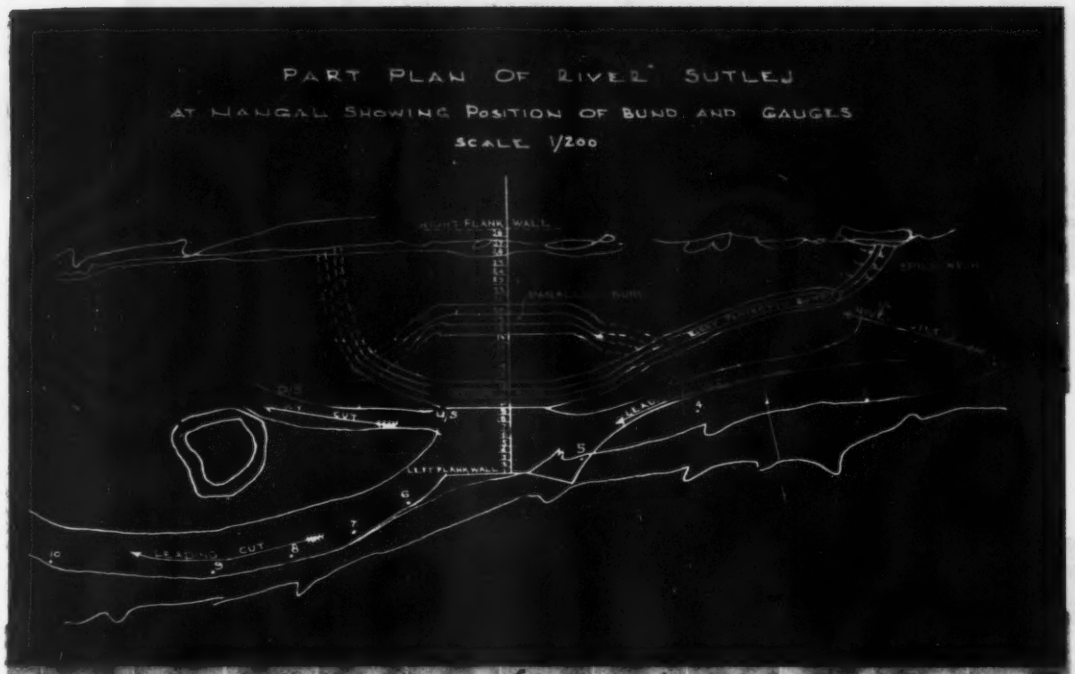


Fig. 2. Part Plan of River Sutlej at Nangal showing position of Bund and Gauges.

Fig. 5 Gauge No. 1

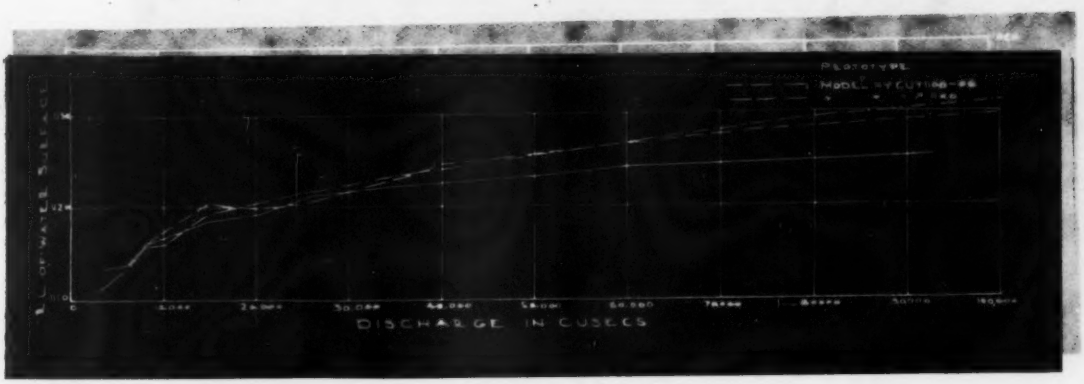


Fig. 6 Gauge No. 2

A Study of River Sutlej

BEHAVIOUR AT NANGAL DAM WITH THE HELP OF MODEL AND A COMPARISON OF MODEL AND PROTOTYPE OBSERVATIONS

——————Prototype
——.——.——Model XY 1108—06
=— —— —— ,, ,, 1100

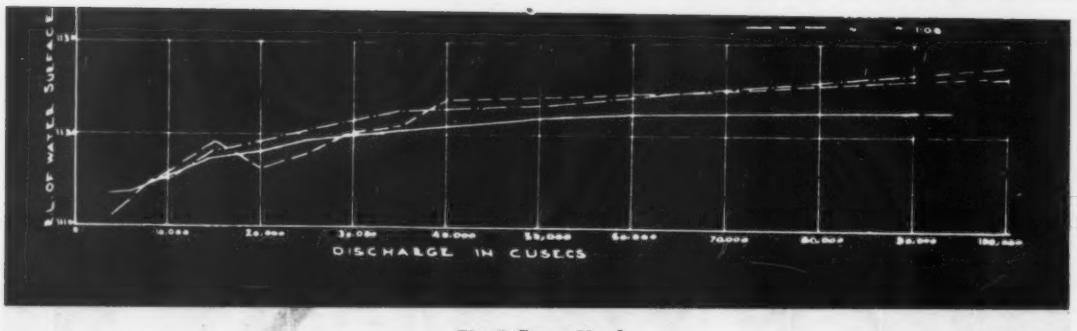


Fig. 7 Gauge No. 3

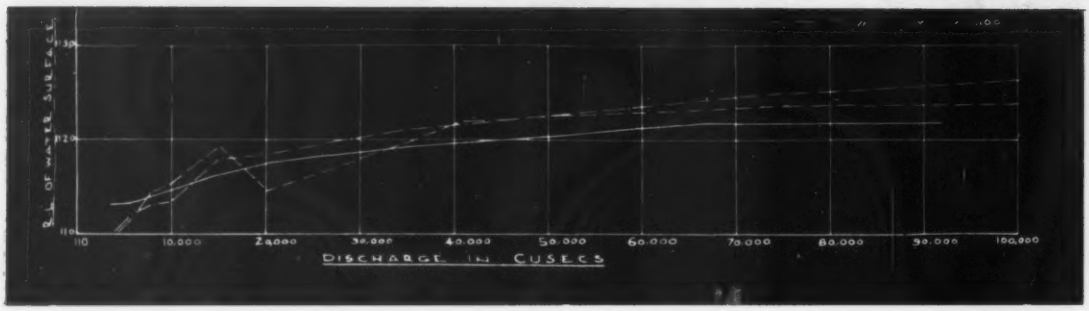


Fig. 8 Gauge No. 4

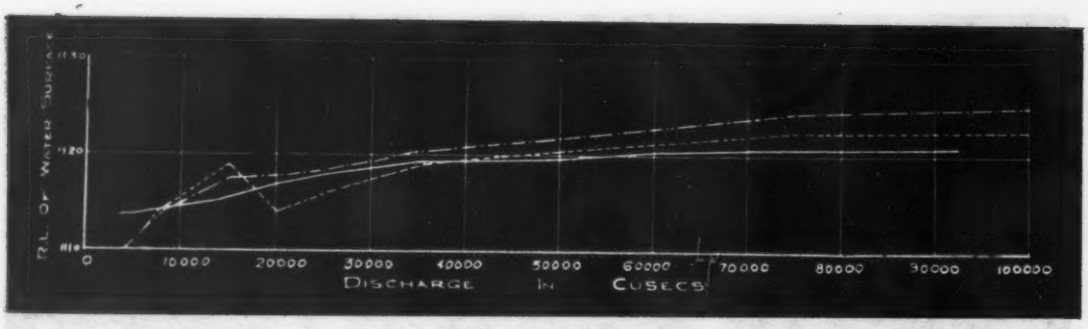


Fig. 9 Gauge No. 5

Please turn over

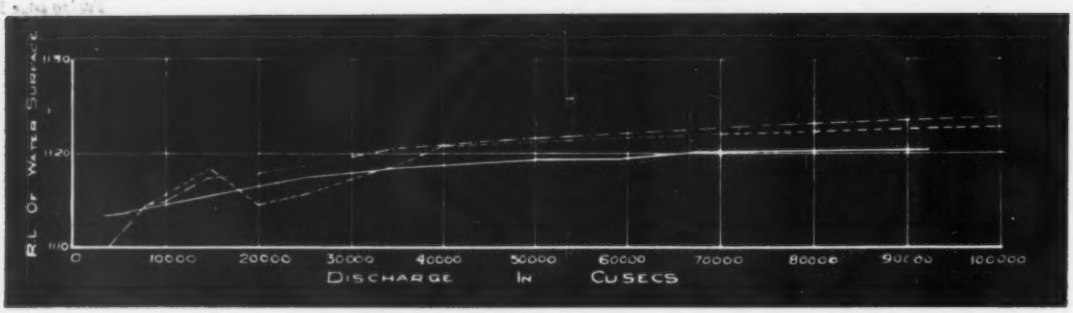


Fig. 10 Gauge No. 6

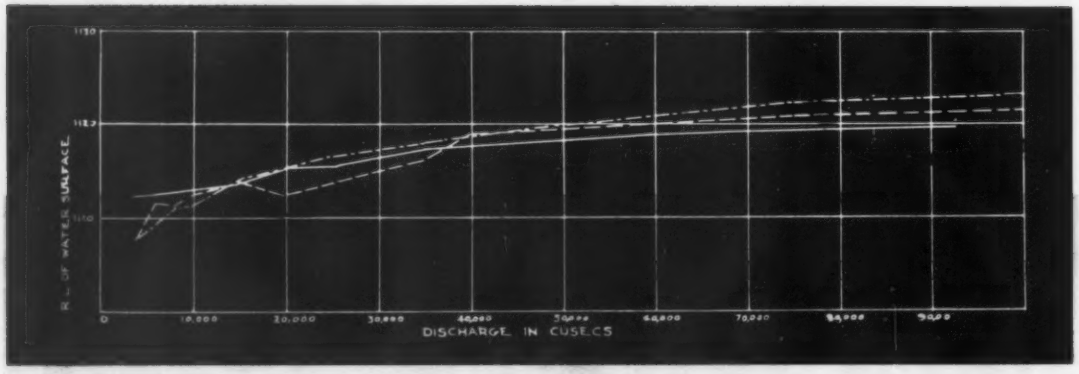


Fig. 11 Gauge No. 7

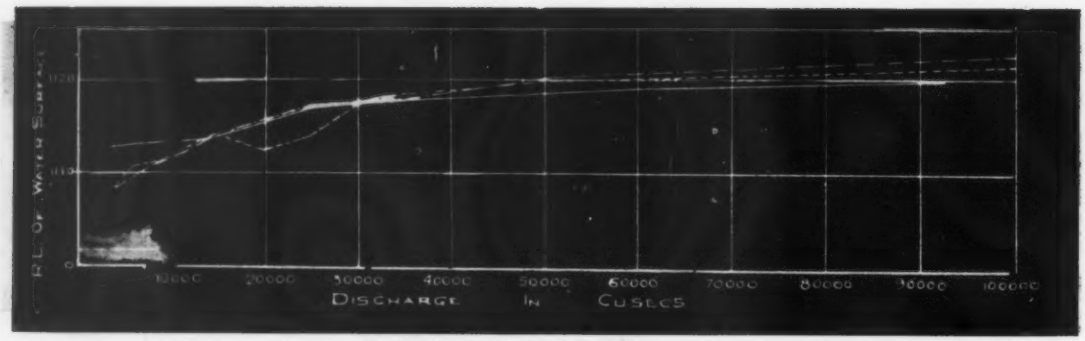


Fig. 12 Gauge No. 8

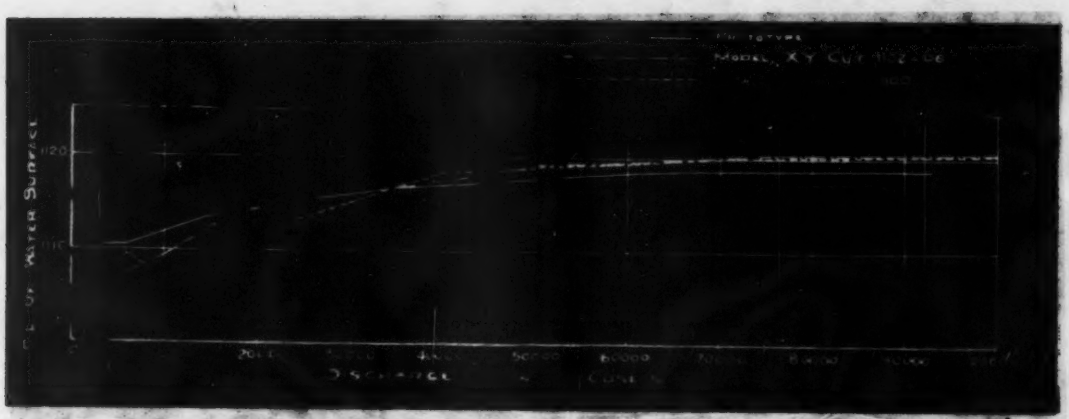


Fig. 13 Gauge No. 9

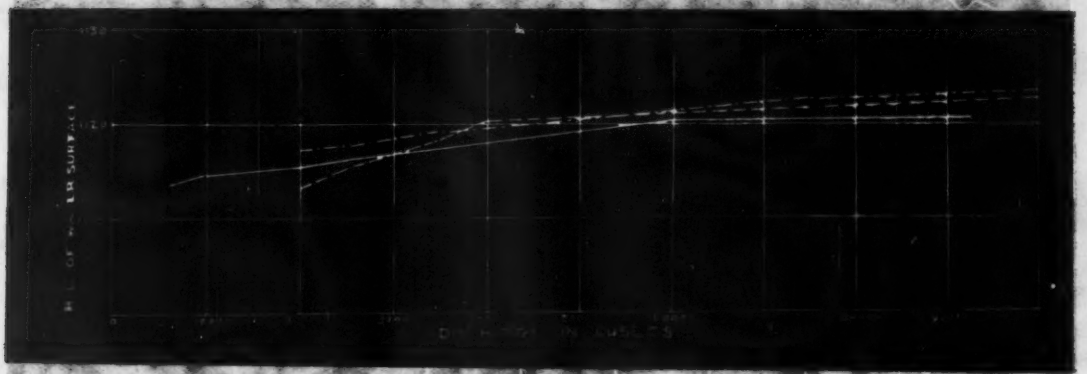


Fig. 14 Gauge No. 10

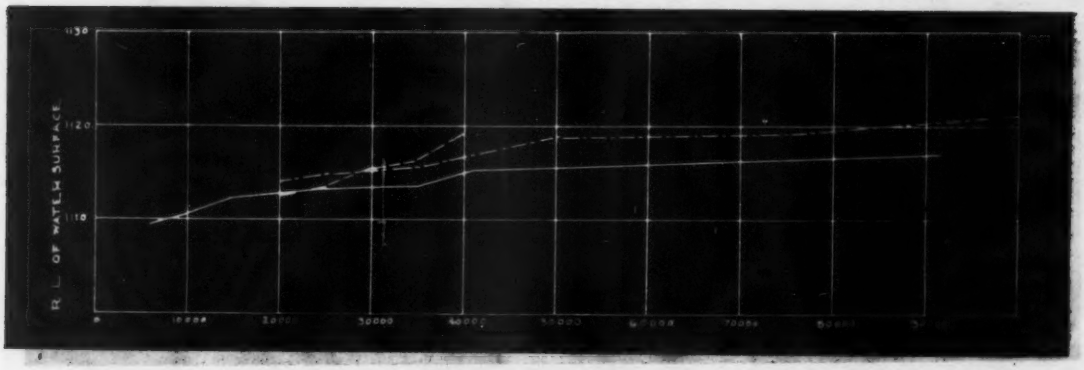


Fig. 15 Gauge No. 11

Studies in the Diversion of Sutlej River at Nangal Dam by means of Models and a Comparison of the Model Results with Prototype Observations

TA

Statement showing water levels obtained on model of Nangal Dam Scale 1/16 during the diversion experiments conducted

Position of Gauges.	*With levels in 4,000 cs discharge*		6,000 *cs*		8,000 *cs*		10,000 *cs*		15,000 *cs*		20,000 *cs befor opening* XY *cu*	
	Left	*Right*	*L*	*R*	*L*	*R*	*L*	*R*	*L*	*R*	*L*	*R*
1 R.D. 200 at the mouth of cut.	1111.4	—	1114.2	—	1116.0	—	1116.4	—	1119.8	—	1122.9	—
1—A Against Diversion bund	11.4	—	14.2	—	16.0	—	16.4	—	19.8	—	22.9	—
1—B against island	—	—	—	—	—	—	—	—	—	—	—	—
2. R.D. 550	11.0	—	13.6	—	15.4	—	16.0	—	19.4	—	22.2	—
3. R.D. 1000	10.4	—	13.0	—	14.7	15.5	15.0	—	18.6	18.7	21.8	21.8
4. R.D. 1350	10.2	—	12.7	—	14.2	—	14.6	—	18.0	—	21.1	—
5. R.D. 1500	10.0	—	12.5	—	14.1	—	14.3	—	17.6	—	20.9	—
6. R.D. 2100	09.6	—	12.3	—	14.0	—	14.2	—	17.2	—	20.5	—
7. R.D. 2600	07.9	05.9	09.8	06.6	11.0	08.0	11.2	8.9	14.0	12.0	16.9	14.3
8 R D 3000	07.4	—	09.1	—	10.4	—	10.6	—	13.4	—	16.1	—
9 R D 3500	06.5	05.8	07.3	06.6	08.9	07.9	09.6	08.8	12.5	11.9	15.6	14.2
Mouth of XY	—	—	—	—	—	—	—	—	—	—	—	14.5
Tail of XY	—	—	—	—	—	—	—	—	—	—	—	14.4

TABLE III

Statement giving comparison of water levels in the diversion cut with bed of XY *cut at R.L.* 1100 *and* 1108-6 *as observed on the model*

Position of gauge	20,000 cs		25,000 cs		35,000 cs		75,000 cs		10,000 cs		150,000 cs	
	XY bed at 1100	XY bed 1108-6	XY 1100	XY 1108-6	1100	1108-6	1100	1108-6	1100	1108-6	1100	1108
1. R.D. 200 at mouth of cut	1120.0	1121.2	1121.1	1122.1	1123.5	1124.4	1129.5	1129.7	1130.4	1131.4	1133.5	1134
1-A Against Diversion bund	20.2	21.3	21.3	22.25	23.8	24.6	29.4	29.9	1130.5	31.6	33.3	34
1-B Against ring bund	—	—	—	—	—	—	28.9	29.3	29.5	31.4	33.0	33
2. R.D. 550	19.5	20.4	20.6	21.9	22.0	23.7	28.6	29.0	29.5	31.0	31.8	32
3. R.D. 1000	16.7	19.6	18.0	20.8	21.0	22.8	25.1	27.4	26.8	28.7	29.4	30
4. R.D. 1350	14.5	18.2	16.2	19.3	19.2	21.6	23.2	24.9	23.7	26.6	27.2	28
5. R.D. 1500	14.4	17.7	15.5	18.8	19.0	20.8	22.8	24.4	23.2	25.7	26.8	27
6. R.D. 2100	14.2	17.3	15.3	18.3	18.4	20.1	22.1	23.6	21.9	24.0	25.8	23
7. R.D. 2600	12.7	15.4	13.9	16.5	16.65	18.3	20.8	22.4	21.9	23.3	25.3	24
8. R.D. 3000	12.4	15.0	16.65	16.0	16.5	17.3	20.6	21.2	21.7	22.2	24.8	24
9. R.D. 3500	12.0	14.75	13.4	15.7	16.25	16.8	20.4	20.9	21.5	21.4	24.4	24
Mouth of XY	13.6	17.10	15.1	18.1	18.1	19.5	21.5	22.6	22.6	23.7	25.3	24
Tail of XY	12.7	14.10	13.8	15.1	16.5	16.25	19.8	19.8	21.3	21.8	—	23

TABLE V

Statement showing the distribution of discharge in the two arms of the river with

Position of observations	River discharges							
	100,000 cs		125,000 cs		150,000 cs		200,000 cs	
	Discharge	%	q	%	q	%	q	%
Left arm	98,000	98	122,000	97.6	135,730	89.3	166,540	83.5
Right arm	2,000	2.0	3,000	2.4	14,270	10.70	33,160	16.5

am
del

TABLE. I.

Statement giving the discharge distribution in the main diversion cut and the XY cut in various river discharges

River Discharge	*Discharge in the diversion cut*	*Discharge in th XY cut*
25,000 cs	12,200 cs	12,800 cs
35,000 cs	15,500 cs	19,500 cs

TABLE II

conducted with R.L. 1108-1106 as the bed level of XY cut at the upstream and downstream ends with discharge from 4,000 to 200,000 cusecs

0 cs before ing XY cut		*29000 cs after opening XY cut*		*25,000 cs*		*35,000 cs*		*50,000 cs*		*75,000 cs*		*100,000 cs*		*150,000 cs*		*200000 cs*	
	R	*L*	*R*	*L*	*R*	*L*	*R*	*L*	*R*	*L*	*R*	*L*	*R*	*L*	*R*	*L*	*R*
9	—	1121.2	—	1122.1	—	1124.4	—	1126.5	—	1129.7	—	1131.4	—	1134.0	—	1135.2	
9	—	21.3	—	22.25	—	24.6	—	26.8	—	29.9	—	1131.6	—	1134.2	—	35.5	
	—	—	—	—	—	—	—	25.6	—	29.3	—	31.4	—	33.7	—	35.4	
2	—	20.4	—	21.9	—	23.7	—	25.7	—	29.0	—	31.0	—	32.6	—	34.9	
8	21.85	19.6	19.9	20.8	20.8	22.8	22.7	24.4	23.7	27.4	26.4	28.7	27.4	30.0	28.4	33.5	
1	—	18.2	—	19.3	—	21.6	—	22.2	—	24.9	—	26.6	—	28.4	—	31.5	
0	—	17.7	—	18.8	—	20.8	—	21.8	—	24.4	—	25.7	—	27.2	—	30.4	
5	—	17.3	—	18.3	—	20.1	—	21.2	—	23.6	—	24.0	—	25.3	—	28.0	
9	14.3	15.4	14.0	6.5	14.9	18.3	15.9	20.4	19.45	22.4	19.5	23.3	21.8	24.9	23.1	27.8	
1	—	15.0	—	16.0	—	17.3	—	19.9	—	21.9	—	22.2	—	24.6	—	27.7	
8	14.2	14.75	13.8	15.7	14.6	16.8	15.8	19.6	19.3	20.9	19.4	21.4	21.4	24.3	22.9	27.5	
	14.5	17.1	—	118.0	—	19.5	—	20.9	—	22.6	—	23.7	—	24.6	—	28.2	
	14.4	14.1	—	15.1	—	16.25	—	19.4	—	19.8	—	21.8	—	23.3	—	26.8	

the model

,000 cs		200,000 cs	
	1108-6	1100	1108-6
5	1134.0	1134.6	1135.2
3	34.2	35.5	35.5
0	33.7	34.8	35.4
8	32.6	33.6	34.9
4	30.0	31.3	33.5
2	28.4	30.3	31.5
8	27.2	29.5	30.5
8	25.3	28.3	28.0
3	24.9	28.0	27.8
8	24.6	27.8	27.7
4	24.3	27.6	27.5
3	24.6	28.16	28.2
	23.3	25.6	26.0

TABLE IV

Statement giving the velocities observed along the protection bund on the left side in different river discharges with crate bar at R. L. 1126.0

	Velocities in feet per second							
R.D. of Bund	100,000	125,000	150,000	200,000	225,000	250,000	300,000	Remarks
Nose	10.88	7.52	7.84	9.64	11.80	16.04	15.04	
100′	5.92	7.08	9.08	13.96	9.08	12.64	—	
200′	5.08	5.56	10.64	10.64	6.00	11.80	—	
300′	5.08	8.48	13.24	11.12	6.00	11.12	—	
400′	9.64	6.40	10.16	12.00	7.84	13.60	—	
500′	7.52	10.16	9.64	10.64	10.16	13.32	—	
600′	8.68	9.60	12.44	11.56	—	9.08	11.12	
700′	12.44	7.84	9.64	10.64	—	8.68	—	
800′	6.00	10.16	8.48	8.48	—	6.80	—	
900′	7.57	10.69	10.64	9.64	—	6.00	—	
1000′	8.48	10.64	12.84	13.60	—	11.16	11.56	
1100′	8.80	14.00	14.36	14.36	—	9.64	—	
1200′	11.12	8.28	12.64	16.40	—	10.88	—	
1300′	7.84	9.64	16.36	11.56	—	12.24	—	
1400′	9.16	6.00	10.16	—	—	—	—	

e river with the crate bar at R.L. 1126.00

00,000 cs		225,000 cs		250,000 cs		300,000 cs	
	%	q	%	q	%	q	%
9	83.5	151,648	80.77	197,718	78.19	215,643	71.88
9	16.5	43,352	19.23	54,282	21.71	84,387	28.12

Discharges experienced during the spring thaw (8,000 and 10,000 cusecs) were next examined. In these discharges movement of bed material started.

Left bank of the cut was eroded at a few places and development of bed also took place.

As a water level of R.L. 1115.5 was obtained at the diversion bund in the discharge of 10,000 cusecs, it was apparent that further observations could be carried out after constructing higher bunds. The diversion bund was therefore, raised and a protection bund constructed at a distance parallel to the diversion cut. Discharges representing the normal river stage, dominant discharge, minimum and high floods were next run. These discharges were equivalent to 25,000, 30,000 and 180,000 cusecs. Fairly rapid development of the cut was observed. In a discharge of 75,000 cusecs some eroded material from the upstream diversion cut became deposited at bays 5 to 7 of the dam. It subsequently moved down in higher discharges. In the discharge of 100,000 cusecs considerable development of the cut occurred. The main flow took place along the alignment of the leading cut. Maximum discharge intensity was observed in bays 5 to 8. The velocity of flow along the bunds was much smaller than that in the centre. The model in operation is shown in Fig. 3

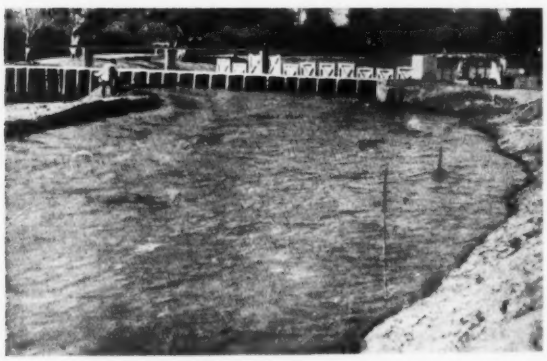


Fig. 3. The model in operation. Diversion has been affected through the eleven bays on the left.

Study No. II : Effect of connecting the upstream left cut with the right on the downstream side

On the basis of the first test a scheme of ring bund was evolved. It was also observed on the model that it the diversion cut could be joined on to the right side downstream of the ring bund the water levels were likely to drop down considerably.

Discharges starting from above the low river stage above 10,000 cusecs were run in this test. Since no appreciable change in the cut was noticeable upto this stage in the previous test, observations upto this discharge were left out. Levels were very much lower than those in the previous tests due to greater expansion space available in lower discharges upto dominant river discharge stage. The cut was linked to the right side at this stage. The levels obtained in higher river discharge stages were lower by 4 to 6 feet. The gap in the bund connecting to the right side is shown in Fig. 4.

Fig. 4. Showing the point from where the diversion cut was connected to the right side. The conditions of flow indicate a normal tendency of the flow to take place in that direction.

Study No. III : Realigning the cut on the basis of study No. II and examination of its behaviour in the higher discharges

In the light of the above studies,

(*i*) the alignment of the ring bund was slightly altered.
(*ii*) Top R.L. of diversion bund was raised to R.L. 1125 instead of R.L. 1115.
(*iii*) Low protection bunds were designed around the bays of the left half still needing completion.
(*iv*) The downstream diversion cut was branched off from the barrage to the right and named XY cut embodying the idea examined in test No. II.
(*v*) The downstream cuts were excavated to R.L. 1100 only.

and the model was operated again.

It was also observed on the prototype that the downstream water level with lower winter discharge was at R.L. 1106 instead of 1104 assumed theoretically. Arrangement for downstream regulator was therefore made to obtain that level to start with.

The model was properly remoulded and all features detailed above were embodied. Discharges from low winter stage to early spring stage were examined. All the necessary observations were taken. Upto river discharge of 20,000 cusecs, the conditions of flow were similar to those already mentioned.

In a discharge of 20,000 cusecs the water level at the mouth of the cut XY was slightly higher than the level of the bela and the water spilled into XY cut bringing the cut into operation. With the cut XY coming into operation, water levels upstream of the dam were considerably affected. A drop of 6′ occurred

in the water level at gauge No. 6 which was close to the dam. Ratio of the discharge in the two cuts was also measured and is given in Table. I

In a discharge of 40,000 cusecs the partition bund in front of bays 10 to 16 became overtopped and the flow started in those bays. However the main flow in high river discharges took place in bays 3 to 9 and comparatively much smaller flow occurred in bays 10 and 16. The cut XY took the major portion of the discharges downstream of the dam as it had developed considerably by attacking its left bank in the discharges above 25,000 cusecs. The point of junction of the diversion bund and the ring bund was attacked. In discharges of 1,50,000 cusecs to 200,000 cusecs representing high floods, the downstream bela got submerged and the river flow was straighted.

Study No. IV : Determination of the levels with the higher bed level of XY cut linking to the right side

In this test all other conditions were the same except the bed levels of the cut XY. At the upstream end the bed of the cut XY was kept at R.L. 1108 while at the downstream and it was kept at R.L. 1106 as against R.L. 1100 in the last test. The change was made at the request of the Superintending Engineer Nangal because of the difficulty of excavation on the prototype.

The cut XY opened in a discharge of 20,000 cusecs as before. The opening of the XY cut affected a reduction of water levels in the main creek both upstream and downstream of the dam. A drop of three feet was observed in the gauge near the dam. At this stage the cut XY took 28% of the total discharge downstream of the dam. The ratio of discharges in the subsequent river stages kept on increasing as the cut XY developed considerably. The discharges in the XY cut are given in Table II.

The left bank of the cut XY got heavily eroded and the river adopted a straight path downstream of the dam. The river action of the junction of the ring bund and the diversion bund was heavy.

A comparison of the water levels obtained in this study with those observed in study No. III showed that except for the reduction in initial drop, the subsequent water levels were practically the same. This was due to the fact that initially higher bed levels did not affect the final development of the cut. The water levels observed in this study are given in Table. III

Study No. V : Determination on the flow conditions and the likely levels if only 9 bays on the left could be ready

In this study the conditions of flow which would be experienced at Nangal in the event of a sudden cloud burst and a consequent freshet coming down the river with the spoils of excavation still undisposed in the river were examined. The number of bays to be used for escapage was restricted to 9 as more bays were not likely to be completed at that stage. Following features were reproduced on the model.

(*i*) River bed laid according to sections received on 3.5.49. It was reported that shoals existed due to spoils of excavation not yet consumed.
(*ii*) Ring bunds were the same as in study IV.
(*iii*) Main leading cut made as in study IV.
(*iv*) Only 9 bays of the dam were used for excapage.

The experiment was repeated and all the discharges from low winter stage to high flood condition were run. The XY cut was opened in 41,000 cusecs discharge. Moreover sequence of rising and falling discharges were examined according to the following programme.

(*i*) From 4,000 to 41,000 cusecs rising river discharge.
(*ii*) From 41,000 dropping gradually to 4,000 cusecs.
(*iii*) Again rising from 20,000 cusecs to 80,000 cusecs and then to 100,000 cusecs representing an early big freshet in the river.
(*iv*) Dropping from 100,000 to 50,000 cusecs again rising to 150,000 cusecs. It was followed of a drop to 75,000 and a rise to 200,000 cusecs.

Observations of gauges etc were taken. It was observed that upto 50,000 cusecs discharge, the values of gauges were the same as in the test No. III and IV. From 50,000 to 150,000 cusecs the value was greater by about three to five feet. Beyond 140,000 the rise was rather a little out of proportion. It may be mentioned here that such contingency never arose.

Gauge discharge curves for all the gauges have been plotted for studies III and IV and are given in fig. 5-15.

Study No. VI : Measures to relieve excessive discharge intensity in the 9 completed bays of the left half

It was evident that in the event of a flood discharge of 200,000 cusecs passing through the 9 completed bays of the left half, the discharge intensity would be 740 cusecs per foot run. This is 170% in excess of the intensity for which the dam is designed. It was, therefore, necessary to provide the necessary relief which should come into operation beyond a certain river discharge. The two possible methods could be (i) the provision of a breaching section in the protection bund opposite the right half or (ii) a stone crate bar or a spill weir at a suitable level.

(1) *A breaching section in the protection bund opposite the right half*

The position of the bund was kept low and was allowed to be overtopped in a river discharge of 75,000 cusecs. It being a shingle bund, erosion was

(*Continued on page* 16)

Flood Control Projects in Second Five Year Plan

By

MINISTRY OF IRRIGATION AND POWER, GOVERNMENT OF INDIA

Floods have almost been a regular feature in various parts of the country but the floods of 1954 were of an exceptional and sustained nature. The grim tragedy that followed in the wake of the floods that year, especially in the north-eastern region of the country, and the large scale destruction of land and property brought home to Government the imperative need of tackling the menace of floods in the country in a coordinated and planned manner. The Minister of Irrigation & Power inspected the floods-affected areas of U. P., Bihar, West Bengal and Assam and assessed the situation created by the floods inconsultation with the various technical experts and representatives of the States concerned. The remedial measures that were proposed to be taken were outlined in the Statement laid on the tables of both the Houses of Parliament of the 3rd Sept.,1954.

Administrative Machinery

The immensity of the problem required suitable administrative machinery to be set up immediately Accordingly, a Central Flood Control Board was constituted under the Chairmanship of the Union Minister of Irrigation & Power to consider the schemes proposed by the States and to draw up a national flood control programme, having due regard to the availability of finance and technical personnel. The States liable to be affected by floods were requested to set up State Flood Control Boards. So far, the States of Andhra, Assam, West Bengal, Bihar, Uttar Pradesh, Orrissa Jammu & Kashmir, Madhya Pradesh, Pepsu, Punjab & Saurashtra have formed their Flood Control Boards. The State Boards are assisted on technical matters by Technical Advisory Committees.

The State Governments are primarily responsible for the planning and execution of flood control works within their territories. As many of the rivers of India traverse more than one State, the problem of flood control in such rivers becomes an inter-state problem. The Central Flood Control Board, therefore, decided at its first meeting held on the 15th September, 1954, that River Commissions should be constituted to deal with problems in the river basins as a whole. Three River Commissions namely the Ganga and the Brahmaputra and Northwest Rivers Commissions were accordingly set up. A similar River Commission is proposed to be set up for Central India.

The Central Flood Control Board has met thrice i.e., on 15th. September, 1954, 14th December, 1954 and 28th March, 1955. Its fourth meeting will be held shortly. The Ganga and Brahmaputra River Commissions have each met twice, the former on the 24th November, 1954 and the 3rd February, 1955 and the latter on the 28th November, 1954 and the 8th February, 1955. The first meeting of the North West Rivers Commission was held on the 20th July, 1955. The various State Flood Control Boards have also held one or more meetings.

A strong technical organisation to co-ordinate all flood control work and assist in drawing up an integrated plan was an immediate necessity. For this purpose a Flood Control Wing was formed, as a part of the Central Water & Power Commission.

The activities of the Flood Control Wing have been divided into the following two main branches :—

(a) Field Investigations (necessary for planning flood control schemes in the various river basins) and (b) Planning and Design (of flood control schemes).

The Flood Control Wing which is a self-contained unit, has been adequately staffed. Apart from carrying out the works mentioned in the preceding para and rendering technical advice to the States, the Wing will secure coordination between the various departments of the Government of India such as the Survey of India, Indian Meteorological Department etc. and and assist in the secretarial work of the Central Flood Control Board. It will compile and correlate all technical data received from the States. Where adequate machinery for the collection of data does not exist in a State, the Wing may take over the work at the request of the State concerned.

Magnitude of the Flood Problem

The inundation caused by floods, almost of regular occurrence, has been extensive in the States of U.P., Bihar, West Bengal and Assam, in 1954 and during the current monsoon.

The most severely affected districts in U.P. are in the eastern part and the damage in this area is caused by the Ghaghra and Rapti rivers, the former submerging annually an area of 3,000 sq. miles and the latter about 1,200 sq. miles. Inundation in the upper reaches of the Burhi Gandak and near the confluence of the Ganga and the Burhi Gandak is also a common feature.

The whole of North Bihar is liable to submersion

during floods which inundate nearly 10,000 sq. miles in the western, central and eastern parts of the State. There are numerous rivers at close intervals, causing spills. The notable rivers which cause havoc are the Burhi Gandak, the Bagmati and the Kamla. The Kosi has its own special problems and the destruction due to it is confined to the central portion of Bihar.

Of the many rivers causing destruction in West Bengal, the rivers Teesta and Torsa stand out prominently. The districts of Jalpaiguri, Cooch-Bihar and parts of Darjeeling are usually affected. Several towns suffer erosion year after year, and the threat continues to exist.

Assam has a large number of rivers running from the hilly catchments into the Brahmaputra. Extensive areas on both the banks of the Brahmaputra were flooded during 1954 and severe erosion occurred at Palasbari and Dibrugarh. A large number of villages were also affected.

The flood problem is no less imminent in the States of Punjab (1), Jammu and Kashmir, Pepsu, Andhra and Orissa.

The State of Punjab has its problem of flood control and erosion and the recurring nature of the floods and devastation caused by them in recent years have necessitated the investigation of methods for control of floods in the Ravi, the Beas, the Sutlej and the Yamuna rivers and for training choes and Khads in Hoshiarpur District. The menace of choes is spreading over Ambala and Jullundur Districts as well. During 1954, the State of Jammu and Kashmir also suffered flood damages and that State has now drawn up schemes for the protection of Srinagar valley from the flood havocs of the Jhelum river.

In PEPSU, the river Beas caused erosion of some villages in Kapurthala District.

Andhra State suffers from extensive damage due to periodical floods in the three major Peninsular rivers the Godavari, the Krishna and the Pennar. Inundation is also caused by the coastal rivers in the Eastern Ghats and by the sea.

Remedial Measures

While occurrence of floods cannot be stopped, it is possible by systematic and sustained efforts to reduce their intensity and thereby prevent the damages caused by them. The measures generally adopted are :

1. Embankments, where feasible, to keep the flood out of areas which are subject to inundation.
2. Storage reservoirs, preferably on the tributaries.
3. Detention basins, where the excess of flood may be stored for a short time.
4. Diversion of the water of one river into another.
5. Increasing the slope of the river by cutting down loops.
6. Dredging and channelling portions of the river, where waterway has been reduced due to silting.
7. Local protection works such as revetments and spurs to safeguard particular areas exposed to the danger of erosion.

After collection of the requisite data, the choice of the appropriate method or combination of methods can be made. Hydraulic model tests are also conducted for an indication of the proper solution.

The preparation of a balanced scheme for a river basin is an extremely complex engineering, economic and social problem. All the known devices must be carefully considered and a suitable combination selected for each river basin.

Difficulties for drawing up comprehensive plans

The main difficulty in drawing up comprehensive plans is the lack of basic technical data. These include the following items :—

(1) Contour survey of the area of the various river basins.
(2) Contour survey of the area effected or likely to be affected by the floods.
(3) Past surveys showing river courses;
(4) Rainfall data for the past years in the catchment area of the river ;
(5) Discharge observations at important sites along the rivers ;
(6) L. Sections, Cross-sections, bed slope observations, high flood water and low flood water levels :
(7) Seismic data of the affected areas ; and
(8) Silt and soil data of the river and of the affected areas. Nevertheless a start has been made and as much of protection afforded in the early stages as possible.

Stage programme

In September 1954 a broad programme of flood protection works was drawn up. This was divided into three phases : (i) Immediate. (ii) Short-term and (iii) Long-term.

(i) *Immediate.*—The first phase will extend over a period of two years. This period will be devoted to intensive investigation and collection of data. Comprehensive plans will also be drawn up and designs and estimates prepared for short-term measures of flood protection.

Some measures such as revetments, construction of spurs and even embankments may be adopted immediately at selected sites.

(ii) *Short-term.*—During the second phase which may be taken to start with the second year and extend to the 6th or the 7th year, flood control measures such as embankments and channel improvements will be undertaken. This type of protection

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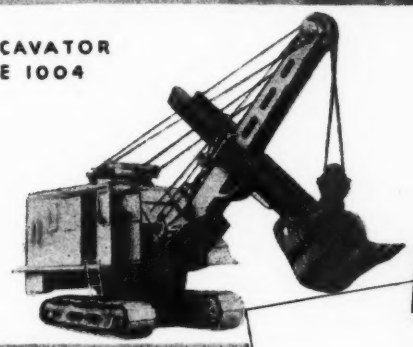

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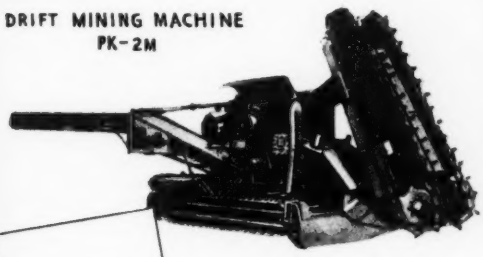

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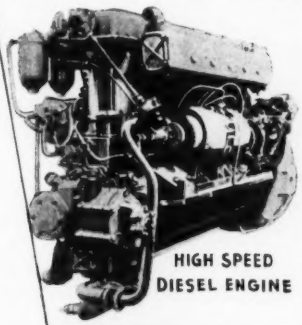

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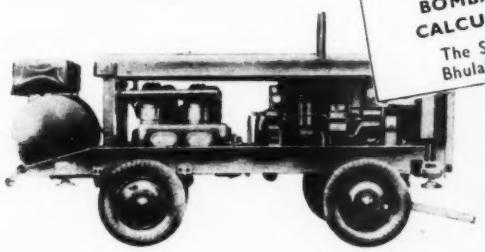

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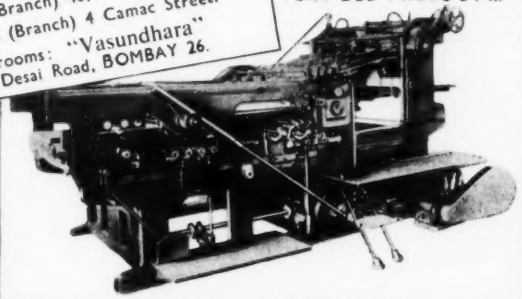

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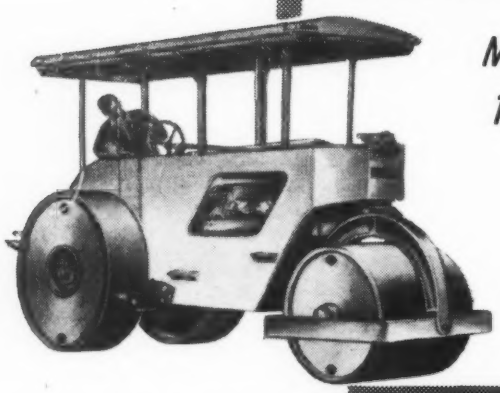

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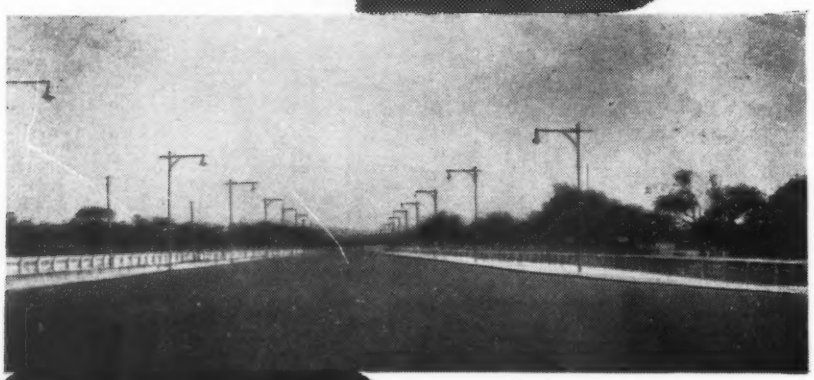

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will be applicable to a major portion of the areas now subject to floods.

(iii) *Long-term.*—The third phase will relate to selecting long-term measure such as the construction of storage reservoirs on tributaries of certain rivers and additional embankments wherever necessary. This may take 3 to 5 years.

Financial Agreements

(i) *Financial Assistance to States.*—As the States are not in a position to finance flood protection works from their own resources they have asked for financial assistance from the Centre. The general pattern of Central assistance to the States undertaking Flood Protection Schemes has now been decided and is the same as that adopted in respect of programmes for the permanent improvement of scarcity affected areas. The assistance will take the form of 30 year loans which will be interest-free for the first 5 years.

(ii) *Scrutiny of schemes before assistance.*—Flood control schemes are classified into "Emergent" and "Ordinary" works. Scrutiny at the Centre is done respect of all works costing more than Rs. 10 lakhs. All the detailed schemes are prepared by the State Governments in consultation with their Technical Committee. After approval by the concerned State Flood Control Boards, the schemes are forwarded to the C.W. & P.C. who carry out the necessary technical scrutiny. Financial scrutiny is simultaneously undertaken by the Ministry of Finance. Financial assistance is provided in the case of emergent works as soon as the scrutiny is over. In the case of ordinary works the schemes are placed before the Central Flood Control Board for approval. Cases where there is a difference of opinion between the C.W. & P.C. and States or where the C.W. & P.C. desire a second opinion, are placed before the River Commission concerned.

(iii) *Schemes costing less than Rs. 10 lakhs.*—The responsibility for the technical scrutiny and issue of financial sanction will be that of the State Government concerned who will consult their Technical Committee, Flood Control Board and Finance Department, before approving the works for execution. It has been decided that all schemes costing less than Rs. 10 lakhs should be sanctioned by the State Governments, even though the collective value of all the Projects might exceed the limit, provided that a programme of work for all the schemes is approved in advance by the Planning Commission.

Review of the Flood Control Schemes under the First Five Year Plan

No provision was made in the First Five Year Plan for any flood control schemes when it was first drawn up. At the time the original Plan was framed, flood control schemes were envisaged only as part of multi-purpose river valley schemes. As already stated in the introductory paragraph, the catastrophic floods of 1954 brought out the urgent need to deal with flood control problem independently of irrigation and power schemes.

Accordingly, after setting up the Administrative machinery and establishing separate organisations for investigations and execution of flood control schemes, the States of Assam, Bihar, Uttar Pradesh, Punjab, Pepsu and Jammu and Kashmir undertook 'emergent' and 'short term' flood protection schemes. Loan assistance to the extent of Rs. 2.31 crores has been rendered to the various States to finance their Flood Protection Works in 1954-55.

The investigations carried out by the States were largely supplemented by those carried out by the C.W. & P.C. Flood Wing, the Survey of India and the India Meteorological Department. The Planning and Designs in connection with specific works and the scrutiny of designs and estimates received from the States have been carried out by the Flood Wing. Full utilization has been made of the existing River Research Institutions in evolving effective river training and emergent protective measures. Foreign Experts were invited to visit flood affected areas in the country and suggested suitable measures and offer comments on the various flood control schemes prepared. The expenditure incurred by the C.W.& P.C. Flood Wing and other Central Departments is being met out of "Revenues".

On the basis of the tentative programme of works to be carried out by the various States in 1955-56, a provision of Rs. 10 corores has been made in the Central Government's Capital Budget for 1955-56 for giving loan assistance to the States in connection with their Flood Control Programme.

Flood Control Schemes under Second Five Year Plan

As already indicated, the State Government's are primarily responsible for the preparation and execution of flood control schemes in their territories. But for lack of essential hydrological and other data, none of the States has been able to draw up comprehensive plans.

It is expected that in the course of the Second Five Year Plan, the necessary surveys will be completed and sufficient data collected to formulate accurate and comprehensive flood control schemes. Nevertheless there are many protection works which have to be carried out on a priority basis and which will eventually form part of the comprehensive plan. Provision for these works has been made in the Second Five Year Plan.

The costs of reservoir schemes which are multi-purpose in character are not included under Flood Control Projects ; only a portion of the costs chargeable to flood control has been included. Soil conservation schemes, which from an important adjunct to flood protection schemes, are not treated as part of flood control schemes, as these will be provided for

by the Central and State Soil Conservation Boards. The important question of soil conservation was, no doubt, considered in the First Five Year Plan, but the measures envisaged therein related largely to the improvement of land use. The role of soil conservation as an important ancillary to flood control schemes is coming to be increasingly recognised. No specific schemes except for one tributary stream in Kosi have been formulated so far, although some of the States are conducting preiminary reconnaissance surveys and studies in this direction.

The investigations that are being carried out by the Central Government organisations, viz., the C.W. & P.C., Survey of India and the Indian Meteorological Department, will have to be carried throughout the Second Plan period. Though the tempo of the intensive investigations which are underway now would slow down after 1956-57, essential investigations like observations of rainfall, river discharge and silt would have to be carried for a further period to build up reliable data. The States have indicated in their programme further areas that they wish to be air-surveyed and levelled and these have accordingly been provided for. The C.W. & P.C. Flood Wing continue to scrutinize the designs and estimates for the schemes proposed in the Second Plan and provision has been made accordingly. These charges will be met out of Revenues.

Programme of expenditure

An approximate break-up of the expenditure for every year for each of the States is given in the above Statements at the end.

Benefits of Flood Control Projects of the Second Five Year Plan

(1) *General*

In flood control planning, it is essential to bear in mind that it is physically impossible to provide 100 per cent. protection against floods. Complete protection against floods in a river basin of appreciable size is practically unknown. Even if it were possible to do so the cost would be prohibitive. The type of flood control works selected for a given basin should therefore be such as will conform to the local conditions and afford appreciable protection at reasonable cost.

In the case of Irrigation & Power projects, it is possible to have a monetary appraisal of the benefits which accrue. Such, however, is not the case with flood control projects. The benefits on account of flood control measures fall under two heads : (i) direct and (ii) indirect.

(i) *Direct Benefits.* Direct benefits are those which are tangible and can be assessed monetarily during the useful life of the flood control works.; for example, the reduction in the monetary value of damage caused by floods to property both movable and immovable and the saving in expenditure on relief measures, as a result of the protection afforded by the construction of flood control works.

The above benefits are to a certain extent offset by the fact that certain areas subject to inundation are deprived of silt which has considerable fertilizing value. It is not easy to assess this loss accurately. A deduction from the direct benefits on this account at the rate of Rs. 1-4-0 per acre has been assumed as reasonable in the calculations that follow.

(ii) *Indirect Benefits.*—The indirect benefits of flood control are intangible and not susceptible of direct monetary evaluation. These broadly consist of (i) prevention of loss of life, health and social and economic security ; and (ii) increase in the general economic activity of the region protected from flood hazards.

(2) *Assessment of the benefits of Flood Control Projects in the Second Five Year Plan*

In the absence of detailed designs and plans for the various schemes proposed for inclusion in the Second Five Year Plan, it is difficult to assess with any degree of accuracy the direct benefits that will accrue from such schemes but an attempt at a rough appraisal has, however, been made in the following paragraphs.

Direct Benefits.—Flood control schemes may be for the sole purpose of affording protection to the flood affected areas or they may be multipurpose in character. In the latter case, projects are designed to confer benefits of irrigation, power, navigation, etc. in addition to flood control.

I.—Flood Control Works combined with other Purposes

(i) *Multipurpose Projects.*—It is often possible to effect economies in river development by formulating integrated proposals with a combination of objects. The reservoir at Hirakud not only provides water for irrigation and the generation of power but will materially assist in moderating the floods in the Mahanadi. The Ramganga Project proposed by U.P., when completed will afford protection, from floods to nearly 3 lakh acres and irrigation facilities to 7 lakh acres, apart from generation of power to the extent of 54,000 K.W. for about 8 months in the year. Somasila Project on the Pennar in the Andhra State is another example of a multipurpose project with conspicuous flood control features.

(ii) *Detention Reservoirs.*—Detention reservoirs designed and constructed on a planned basis can, besides providing relief to flood-affected areas, irrigate land in the commanded areas. Pisciculture can be promoted which will be a source of revenue. The U.P. Government have, in their plan, included the construction of a number of such reservoirs which will afford, besides flood protection, irrigation facilities for small blocks of land varying from 1 thousand to

TABLE I

facing page 14

Programme of Expenditure for Flood Control Works for the Second Five Year Plan

Sl No.	*Name of State*	*Estimated cost of works crores*	*Expenditure in Crores of Rupees*					*Total expenditure in 2nd Plan period*	*Remarks*
			1956-57	1957-58	1958-59	1959-60	1960-61		
1	2	3	4	5	6	7	8	9	10
	Works undertaken by Central Government Departments namely Survey of India, Meteorological Department and C.W. & P. C. (Flood-Wing)	5.87	1.68	1.52	1.14	0.78	0.75	5.87	
	STATES								
1.	Assam	26.11	4.63	4.22	4.52	3.12	1.37	17.86	
2.	Bengal	10.00	2.00	2.00	2.00	2.00	2.00	10.00	Details still awaited from Bengal State.
3.	Bihar	53.00	13.60	4.85	4.25	4.35	4.45	31.50	This includes Rs 9. crores for Kosi Project Flood Banks.
4.	Uttar Pradesh ..	49.72	8.00	6.50	5.50	4.00	3.00	27.00	
5.	Andhra	14.99	3.77	3.75	2.91	1.36	1.00	12.79	C.E. Andhra has asked for Rs. 25 crores.
6.	Punjab	1.10	0.22	0.22	0.22	0.22	0.22	1.10	
	Pepsu	0.52	0.16	0.06	0.06	0.06	0.06	0.40	
8.	Jammu and Kashmir	4.80	0.04	0.40	0.50	0.50	0.60	2.40	
9.	Orissa	1.09	0.25	0.25	0.25	0.25	0.09	1.09	Supplementary list awaited.
10.	Saurashtra	0.50	0.10	0.10	0.10	0.10	0.10	0.50	Detailds awaited.
11.	Bombay	1.50	0.40	0.40	0.40	0.15	0.15	1.50	Do.
12.	Tripura	0.50	0.10	0.10	0.10	0.10	0.10	0.50	Do.
13.	Madhya Pradesh ..	1.50	0.30	0.30	0.30	0.30	0.30	1.50	Do.
14.	Other States and Works not yet investigated.	3.14	0.62	0.63	0.63	0.63	0.63	3.14	Do.
	TOTAL ..	174.37	36.23	25.30	22.88	17.92	14.82	117.15	*Say* 117.0 Crores

TABLE II

Programme of Expenditure for Flood Control Works undertaken by Centre for Second Five Year Plan

Sl. No.	*Particulars of work*	*Estimated cost of work in crores*	*Expenditure in Crores of Rupees*					*Total expenditure in 2nd Plan Period*	*Remarks*
			1956-57	1957-58	1958-59	1959-60	1960-61		
1.	Investigations by C.W. & P.C. Flood Wing	2.72	0.74	0.62	0.46	0.46	0.44	2.72	Crores
2.	Survey of India	2.50	0.81	0.75	0.52	0.20	0.22	2.50	Crores
3.	India Meteorological Department.	.25	.03	.05	.06	.06	.05	.25	Crores
4.	Central Silt and Construction Materials Laboratory at Delhi.	.20	.05	.05	.05	.03	02	.02	Crores
5.	Medel tests for river training and protective works.	.20	.05	.05	.05	.03	.02	.02	Crores
	TOTAL	5.87	1.68	1.52	1.14	0.78	0.75	5.87	

TABLE III

Table showing annual inundated areas and probable extent of areas benefited at the end of the Second Five Year Plan

	State	*Area inundated in square miles (General Average)*	*Are a benefited by flood control schemes in square miles*
1.	Assam	12,150	6,000
2.	West Bengal	1,000	500
3.	North Bihar	10,070	4,280
4.	Uttar Pradesh	5,150	3,000
5.	Other States	1,500	750
		29,870	14,530
	Probable are benefited by Flood Control Projects at the end of the Second Year Plan.		14,530 sq. miles or 94 lakhs acres approximately.

20 thousand acres. Many of these schemes show a financial return of 1 to 3 per cent.

II.— Flood Protection Works

(i) *Marginal Embankments.*—Marginal embankments are constructed along the main channels of some rivers which are not capable of carrying the full discharge during floods. Such embankments are essentially meant to prevent inundation of the river valleys. Though the benefits arising from these works are mainly prevented, it is often possible to divert the surplus water through sluices provided in the embankments at proper sites and carry out irrigation in certain commanded areas. This would enable the use of the water, carrying fertilizing silt, for irrigation purposes. The Government of Bihar have in their plan a proposal for the construction of parallel embankments along both the banks of the Bagmati and the Kamla rivers, provided with weirs at suitable places.

(ii) *Spurs, revetments, dredging, etc.*—These measures are undertaken to prevent erosion of lands. They do not yield any direct return to Governmnt on the capital invested but will bring relief to the hard-hit flood affected areas and may prevent serious damage to towns like Dibrugarh.

Savings in Flood Relief Expenditure

Incalculable damage has been caused by floods in the various parts of the country. Crores of rupees are being spent every year on gratuitous relief and other relief measures. Table I shows the amount spent on such measures for the years 1950 and 1954, as far as information is available. The saving of this heavy annual expenditure can be looked upon as a direct benefit arising out of flood control measures. The total expenditure on relief measures during the years 1950-1954, according to rough calculations amounts to Rs. 16 crores ; it is possible that the actual figures are much greater. The agricultural and rehabilitation loans that are advanced during floods are not always repaid in their entirety, especially in areas where floods are a regular feature. For purposes of calculating the losses on account of floods, it has been assumed that only 50 per cent. of the loans will be repaid. Making allowance for these factors, the annual loss on account of relief easures can be taken to be Rs. 4 crores.

Reduction in direct benefits

Table II gives the approximate areas inundated in the various States annually and the probable extent of areas that will receive the benefits of flood control works at the end of the Second Plan. These protected areas will be deprived of the fertilizing silt of the flood waters. It will be noticed that nearly 14,350 sq. miles or 93 lakh acres will be protected from floods. Assuming that 80 per cent. of the area is cultivable, the effective area would come to about 75 lakh acres. Taking the value of manurial silt at an average of Rs. 1-4-0 per acre, the annual loss on this account would be Rs. 94 lakhs or say Rs. 1 crore.

The net annual direct benefit would therefore be of the order of Rs. 19 crores over a period of five years.

Indirect Benefits

The principal benefits accruing from flood control works are really indirect. Though no direct return to Government on the capital invested is assured flood control measures will save lakhs of habitations and millions of acres of cultivated areas from the ravages of flood. They will prevent large scale damage to public utilities and promote a feeling of security amongst the population which is exposed to peril of floods.

Table III shows the figures of flood damages for the years 1950-1954. Where information is not available, the figures have been computed on the basis of those in comparable years. The Table shows that damage to the extent of Rs. 150 crores has occurred in 1950-54. On this basis, the average annual damage can be taken to be Rs. 30 crores.

The facts brought out above fully justify the undertaking of the flood control projects on a sufficiently large scale. Assuming that the annual loss is as low as Rs. 15 crores as against Rs. 30 crores worked out above, the total loss on this account in the next five years would be Rs. 75 crores. By adding to this the amount likely to be spent on flood relief measures viz. Rs. 19 crores, the total value of damages and direct expenditure due to floods during the period of the Second Plan would work out to Rs. 94 crores. Even if 30 per cent. of the damage can be reduced at the end of the Second Five Year Plan, the investment proposed on flood control projects in the Second Plan, namely Rs. 117 crores would not be unreasonable. Government have been advised that at the end of the Second Plan, the flood damages can be reduced by 50 per cent, if a sum of Rs. 117 crores is made available for flood control works.

Public Cooperation

The Planning Commission, while drawing up the First Five Year Plan had rightly laid stress on the role of Public Cooperation in national development, to enable individuals and groups to make their maximum contribution in the implementation of the Plan.

A very good beginning has been made in this direction. In the Kosi and North Bihar areas, work is being done on a cooperative basis through Gram-Panchayats. People are also eagerly coming forward to give a helping hand under the organisation of Bharat Sewak Samaj. Cultural facilities such as radio sets, newspapers, cinemas, etc., are being made available to the workers. The auxiliary Cadet Corps has also been mobilised to do some part of the work on the Kosi Project. In Uttar Pradesh, a great part of the work on raising the level of villages affected by floods is being done by the villagers themselves. At Dibrugarh, in Assam, even students are voluntarily

doing manual labour in the construction of project works. In Punjab also, villagers and students are actively co-operating with the Government. It is expected that with full public co-operation the Flood Control Project envisaged in the Second Five Year Plan will be completed well within the provision even if there were any rise in price levels.

Conclusion

Recurrent floods lead to rapid deterioration of an already under-developed economy. The flood control Schemes cannot be judged by strict and orthodox standards to justify the execution of irrigation and power Schemes. The former have to be viewed in the broader context of loss of national wealth, fall in economic potential and, lowering in the standard of health and sanitation and other socio-economic factors. In this sense the flood control Schemes have to be regarded as national insurance measures.

Flood Control Schemes will, therefore, bring security to the flood afflicted areas, help in the development of the areas by the full utilization of the manpower and resources available therein. They will raise the living standards of the masses and open out opportunities for a richer and more varied life. There is no doubt that the indirect benefits that will accrue from the Schemes will more than justify the large investment made on their execution.

Note: The above draft plan is being further scrutinised and revised in the light of experiences of floods in Orissa, the Punjab, the U.P., etc. —*Editor.*

(*Continued from page* 10)

Studies in the Diversion of Sutlej River at Nangal Dam by means of Models and a Comparison of the Model Results with Prototype Observations

fairly heavy. Water level at gauge No. 1 dropped by three feet. The nose of the bund was under direct attack. On the right side flow took place along the bund upto R.D. 400. Beyond this point the flow became central and there was back flow along the bund. On the left side flow was hugging all along the bund and it was partly eroding the bund. The right channel was carrying 33% of the discharge.

With the rise in the river discharge, the nose came under heavy action and the stone pitching provided at the nose started slipping down. Right side deveoped considerably and in a river discharge of 150,000 cusecs 50% discharge was going in the right side. The bed level at the breaching section was at R.L. 1107. This would mean that once a breach was made, the development would be very quick and the bed levels at the breaching section would become so low that after the flood had subsided it will become difficult to switch the water back to the left side without proper diversion.

This scheme was, therefore, not recommended.

ii) A crate bar or a spill weir at a suitable level

A crate bar R.L. 1127 and 1126 respectively was examined. The bar was constructed 50 feet downstream of the protection bund and the bund was pitched with stone upto 400′ length on the right side and along its entire length on the left side. The nose was adequately protected. Examination in varying river discharges showed that the left side had developed considerably. The water levels had dropped down and thus the crate bar at R.L. 1127 permitted a smaller proportion of discharge to go over it. The level of the crate bar had to the lowered to R.L. 1126.0. At this stage water levels in the river for 1,00,000 cusecs discharge on the prototype were available. The model was checked up to see if those levels could be reproduced. The crate bar in the breaching section was, therefore kept closed and a discharge equivalent to 100,000 cusecs was run on the model. The gauge obtained on the model at the dam site corresponded closely to that on the prototype. The gauge at the nose of the bund was slightly higher due to local afflux. The model was then run with discharges rising upto 300,000 cusecs and the distribution of discharge in the two halves of the river was observed. Results of observations are given to Table IV. There was no action on the nose due to oblique placement of the crate bar. There was no action no the bund on the right side downstream of the crate bar. The velocity observations along the bund are given in Table V.

A crate bar was constructed on the prototype at the Nangal Dam at the corresponding position. It came into action in the following discharges :

Date	*River discharge*	*Discharge passed over the crate bar*
3.9.50	109,000 cs	3,000 cs
29.8.50	128,000 cs	10,000 cs
28.8.50	180,000 cs	15,500 cs
16.8.50	164,000 cs	15,000 cs

The results are very similar to those obtained on the model.

Observations on the Prototype and comparison of the results with those Predicated on the Model

After the river was diverted on the prototype according to the programme studied on the model, observations were taken on the prototype at corresponding points. The water levels observed on the gauges constructed at corresponding position compared well with the observations made on the model. This is shown in Figs 5 to 15. It will be seen that the agreement is very close for all discharges for gauges No. 6 to XY gauges. In gauges No. 1 to 5, there is a little divergence in discharges above 50,000 cusecs the model gauges are a little higher. The model behaviour has shown to be similar to the prototype.

Role of Forests in Flood Control: Bhakra-Nangal Project

B. SINGH

Floods have caused tremendous damage in the past : the principal reason being that the hill slopes have been stripped off of their vegetative cover. The rainfall being mostly limited to short periods in the year takes the form of highly concentrated showers at times. Regulation of run-off is, therefore, essential in the interests of flood control. Dense vegetative cover provides effective check against rapid run-off, floods and consequently decrease in transportation of silt. This paper is written with particular reference to Bhakra-Nangal Project. The Bhakra reservoir will receive the drainage of 7657.7 square miles out of which forest area amounts to 775 square miles only. This works out to 10% of the total catchment of the reservoir. For proper flood control, afforestation and soil conservation measures are essential in the catchment. The cost of operations is estimated at Rs 15 crores which works out to 9% of the capital outlay on the Bhakra Project. We draw the attention of our engineers and administrators to this very interesting contribution.

AUTHOR

Floods have caused tremendous damage in the past in many countries of the world notably in Egypt and China. Floods and famine in India have come in regular succession in the past 1,000 years, but turning to the pages of old Indian history of the pre-Puranic period, reference do indicate that the streams and rivers had well defined banks, civilization flourished on the banks of big rivers and reached its zenith. The increase in population and the general rise in standard of living of the people resulted in hunger for land and forest products ; in consequence of which large tracts were cleared of forest growth. The pressure continued increasing so much that even sloping lands and hills were not spared and were stripped off their protective cover. A marked retrogression has slipped in during the past 30-40 years. Consequently the Indus in Sind, the Kosi in Bihar, the Brahmaputra in Assam and the Tungabhadra in Deccan have often run in high floods, thereby causing considerable havoc. Floods of local importance in each State are innumerable to be mentioned here. The recent floods in Bihar and Assam have demonstrated as if the mountains are on the march down to the Sea. Last year the Kosi—the river of sorrow of North Bihar—caused untold suffering and devastation.

Precipitation and Run-off

Rainfall in India, being mostly limited to short period and confined to certain seasons of the year, takes the form of highly concentrated showers at times, and is, therefore, an important feature deserving careful consideration in appraisal of anticipated run-off and in determining the frequency, duration and intensity of floods. The nature has provided a a balance or an equilibrium in the water regime and when it is seriously upset by excessive interference by man, floods, avalanches, or drought follow in succession.

Wherever indiscriminate fellings of trees and clearance of vegetative growth is followed by cultivation along hill slopes in the catchment areas, the floods originate in the rivers. The surface run-off rushes down too rapidly over the denuded slope, increasing in velocity and intensity, carrying heavy loads of silt. Regulation of run-off is, therefore, the essence of flood control.

B. Singh, *Conservator of Forests (D.S.), PEPSU.*

Role of Vegetative Cover in regulation of Run-off

The philosophy of the role of forests, in fact, is based on its ability in prolonging the water cycle commencing from precipitation to the final discharge of the water into the Sea. The duration and the manner in which falling raindrops are held in suspension, the capacity with which certain percentage of water is passed down to the underground storage chambers, and the mode how the surface run-off is discharged into streams, demonstrate the role of forests on the control of flood and in the conservation of soil.

Compare run-off of a stream after a shower of rain inside canopied forest with that in the bare area adjoining it. In the forest, the canopy of trees and bushes breaks the speed of raindrops. It sprays on to the porous humus layer which absorbs it like a sponge and helps it to infiltrate into the subsoil below, where it is stored before it is released in the form of springs. The water in the stream runs clear and shinning. It conveys a sense of cleanliness, brightness and happiness.

In the adjoining bare area, the raindrops beat hard on the exposed soil, rush down the slope, join stream, gather momentum,cause flood and carry large quantities of earth, shingle and boulders. The water gets discoloured and muddy. It presents a depressing sight and conveys a sense of frustration, loss and fear.

It indicates that dense vegetative cover alone can provide effective check against rapid run-off

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floods, and consequently decrease in the transportation of silt.

The Catchments and River Valley Projects

The great rivers, though originating from the glaciers in the high mountains, mostly in the zone of perpetual snow above the upper limit of forest growth, receive the entire drainage of their catchments. The approximate length and catchment area of some important rivers are as under :—

Name of River	*Hill catchment area in sq. miles*	*Length of river in miles*
1. Indus ..	79,400	1,830
1. Ganges ..	8,600	1,500
3. Brahamputra	1,47,500	1,800

Floods not only upset the water regime of the rivers and streams, but also cause heavy damage to cultivation, habitation, roads, buildings, and railways and create a serious danger to the life span of the reservoirs of big River Valley Projects.

The Central Board of Irrigation adopted a resolution in 1938 that "Evils of denudation in India are so serious and wide spread that action for its further prevention should be taken without further delay."

It further pointed out that "dangerous effects of deforestation on irrigation are :

(*i*) The increase of intensity of floods.
(*ii*) The decrease of flow in rivers in dry weather."

In addition to above, silting of reservoirs is also an important factor worthy of serious consideration.

Government of India has taken in hand about 160 River Valley Projects which are under execution or investigation. Out of them 9 are major projects, upon which depends the prosperity of the millions of people. Therefore, there is a need for focussing greater attention on the subject with special reference to river valley projects under construction at present.

Bhakra Dam

Bhakra Dam will rank as the highest straight gravity dam in the World, carrying a storage capacity of 7.4 million acres-feet of water. The total area likely to be submerged under the reservoir will be about 50 square miles. The storage will provide irrigation facilities for 10 million acres of land and generate about 4 lacs kW. electric energy. This is the biggest single multi-purpose project under construction in the country. Agricultural and industrial development and consequently the economic stability of the States of the Punjab, PEPSU and Rajasthan depend on the successful working of the Project.

Gulley erosion in Shiwalik Hills (P E P S U).

The Catchment of Bhakra Dam in the Punjab will receive the drainage of 7657.7 sq. miles, out of which forest area amounts to 3706.1 sq miles only. The figures collected by the Bhakra Control Board show 445.2 sq. miles under cultivation, 3,051 sq. miles under habitation, roads, etc. ; while the balance area of 455.4 sq. miles consists of wastes. Out of total forest area of 23,71,839 acres (3706.1 sq. miles) as much as 18,75,840 acres in Sipiti are waste lands which are proposed to be declared as undemarcated protected forests. Thus for practical purposes, forest area amounts to 775 sq. miles or 4,95,999 acres, which is only 10% of the total catchment of the reservoir.

The hydrological data of the catchment of the Sutlej is as under:—

Catchment area at debouchment in plains in sq. miles	*Area under glaciers sq. miles*	*Maximum recorded flooded cusecs*	*Run-off in acre feet*	*Percentage run-off of rainfall*
23,400	2,468	4,00,000	1,39,38,000	56.67

Denudation in Hoshiarpur Shiwaliks

The destruction of forest in any catchment area is followed by floods of high intensity in the streams. The tract gets desiccated, springs dry up, and water table falls.

This is categorically true of the Hoshiarpur district. The unrestricted felling of trees and bushes and the increased onslaught of erosion as is proved by grazing of cattle sheep and goat in the Shiwalik hills led to the drying up of streams (Chos) and springs, with a fall in the water table throughout the district in the plain area over a strip of 80 miles in length and 25 miles in width from Hoshiarpur down to Jullundur District. The hills are badly cut up into gullies, and chos have widened.

There is a popular belief in the people that the destruction of forest lead to a decrease in rainfall, though it cannot be definitly proved. G. S. Puri in his article in the *Indian Forester* for February 1949, says that "During the year 1862-1930 rainfall had steadily decreased from 36.70 to 26.61 inches."

In the Hoshiarpur Shiwaliks, continuous destruction of the forest from year 1850 onward resulted in the following figures of land under chos in the district, so commonly quoted in various articles :—

Year	*Area under Chos*
	acres
1852	48,206
1884	80,057
1897	94,236
1943	1,50,000

The common feature of the Hoshiarpur Shiwaliks is peak floods of dangerous and sudden intensity in the streams (Chcs) followed by rapid desiccation. Within two hours of rainfall in the hills, water rushes down in the streams causing floods and two hours after the rain stops in the hills, the streams run dry.

Between 1900-1942, water table continued to fall by 9 inches to 1 foot or so annually and by then it had fallen by 20-30 feet in various tracts. A large number of wells has gone dry. What is true of Hoshiarpur Shiwaliks is equally true of Shiwaliks in the PEPSU forming catchment area of important Sirsa and Ghaggar Rivers and may be true of many other areas forming catchment areas of India's most valuable multi-purpose river valley projects. Similarly due to destruction of forests in Mahendragarh district of PEPSU bordering Rajasthan desert, the water table has fallen by 20-30 feet in the past 50 years.

Restoration of Vegetation

The Forest Department seriously took up the question of closing the areas to grazing and browsing, cutting of trees and bushes and afforestation from 1936 onward. By 1947 more than four lacs acres of private forests were under the control of the Forest Department.

Stream training Works in Kanahan Nadi.

As a result of continuous efforts of the Forest Department large tracts in the hills and along streams were afforested. It had a significant effect. By 1943, the water table had stopped falling. Since then water has been rising by 9 inches to 1 foot every year and within another 20-30 years, normal conditions are likely to be restored.

Is it not sufficient proof to show that the destruction of forests in the Shiwalik hills was responsible for the fall in water table and with re-afforestation water table has again risen.

PEPSU Shiwaliks

The Shiwaliks in PEPSU forming catchment area of Ghaggar and Sirsa Rivers present a puzzling entanglement of fissure, gullies, ravines and scrapped walls, and are in a serious state of erosion. The total area involved is 1,76,079 acres or 275.12 sq miles. During rains, over-brimming rivulets and roaring streams offer a spectacular scene of muddy thrust taking with it unmeasurable quantities of clay, sand, stone and boulders. Sirsa joins Sutlej near Rupar few miles above Sirhind canal head works and unloads thousands of tons of silt into it every year. A scheme was prepared to arrest the process of destruction and the work is in progress now.

Movement of Silt

The absence of vegetation accelerates the velocity of the run-off and the erosive power of a stream which varies as the square of its velocity. If the velocity increases ten times, its power to cut and destroy its bed and banks increases 100 times. Again the transporting power of water varies as the sixth power to move detritus mixed with water increases one million times.

Hundred years ago, Everest calculated that the Ganges conveyed more than 35,60,00,000 tons of sand and clay to the Bay of Bengal on an average of 9,00,000 tons of silt every day. The Indus carries 10,00,000 tons a day when in flood. A large number of rivers in India, U.S.A., Egypt and Europe, etc., show that annual silt yield of river is about 75 acre feet per 100 square miles of catchment (as mentioned in 1940 proceedings of the Central Board of Irrigation).

Khair Sowings of 1952-53 in Khal Prempura.

The figures are quoted from Dr. Gorrie's book on Soil and Water Conservation in the Punjab.

Discharge in cusecs	*Silt carried in acres per day*	*Proportion of Silt in water*
20,000	15	1 in 2667
50,000	188	1 in 533
1,00,000	875	1 in 229
1,50,000	2,063	1 in 145

In 1937, in the Nurpur run-off plots (Kangra District) when a 9.8 inches storm fell in 19 hours in July, showed that on a 1 in 4 slopes, the run-off from areas representing "grazing" was 95% of total rain, whereas from areas of uncut grass and under scrub cover, it was only 20%. Soil lost in lb. per acre was 20,023 from the "Grazed" plot against 273 from "Grass and Scrub" plot for this one storm. The detailed result of the run-off was as under :—

	Grass 80% cover	*Grass shrubs 90% cover*	*Bare Soil*
Percentage of rain which ran-off	%	%	%
Out of total 46 inches on 32 wet days during July-October 1937 ..	7	2.5	25
Out of total 5¼ inches in 4 hours the heaviest single storm ..	2.2	1.7	6

In Hoshiarpur on the pebbly uplands on Gahshankar tehsil at Polian, following data for individual rain storms comparing run-off from bushes, grass and bare soil was collected.

Kanitkar's Sholapur data for run-off plots with a fall of 1.18%(1 in 85) in fields of Deccan Trap soil with a rainfall averaging 26 inches from a series of comparable plots under different soil covers and soil working, shows that annual average soil losses varied from 0.64 tons per acre for grass to 16.40 tons on a bare fallow, 30.19 tons from shallow cultivation and 43.99 tons for deep cultivation. It clearly shows that soil from cultivation is much more as compared with grass or forest cover. The slope in the hills is steep and with the exception of rice fields others are not terraced. The quantity of soil loss from cultivated lands situated in the catchment area, therefore, must be colossal.

General condition of the Bhakra Dam Catchment

The highest part of the catchment of the Bhakra Dam lies in Sipity in the Punjab. Its condition is said to be bad. The bulk of lower part of the catchment area falls in Himachal Pradesh. The condition of forest area in Suket Forest Division is deplorable. As a result of continuous centuries old denudation of forests, large tracts of sloping hills have been laid bare of forest cover. Large number of flocks of sheep and goats sweep the area every winter and browse the vegetation down to the ground.

Principle of Anti-Erosion

As a matter of principle, the anti-erosion measures or the work relating to regulation of run-off should start from the top of the catchment and proceed downward. As the catchment area is too large, this is sure to take a very long time. The only alternative lies in the treatment of each catchment of a stream forming tributary of the Sutlej above Bhakra Dam simultaneously. In consideration of this fact, PEPSU has taken up the work in hand, although at higher regions it may not have been commenced as yet.

Cost of the Operations

It was estimated by the Bhakra Control Board that half of the cultivated land need intensive soil conservation measures. Similarly practically whole of the area of private forests and waste lands will have to be properly treated. The cost of the operation will work out to Rs. 15 crores as under :—

		Rs.
1. Cultivated Lands—Terracing, levelling and embanking @ Rs. 45 per acre ..	$2,84,923/2 \times 45 =$	63,90,772
2. Treatment of wastes, trenching Check-damming and afforestation @ Rs. 65 per acre ..		14,19,91,070
	TOTAL ..	14,83,81,842

This works out to a little more than 9% of the capital outlay on Bhakra Project. A well known

Date	*Rainfall in inches*	*Duration of storm*	*Intensity in inches per hr*	*Run-off of rain cubic cm.*			*Silt loss*		
		hrs.		*Bushes grass*	*Grass*	*Bare*	*Bushes*	*Grass*	*Bare*
22-7-40	3.28	10	0.32	1350	12200	14525	7	18	95
1-8-40	2.67	6	0.44	700	8900	16800	9	34	95
2-8-40	1.75	2	0.88	425	8625	10500	5	17	41
8-8-40	1.71	1	1.14	925	7150	8700	13	22	40

(Continued on page 30)

Problems of Israel's Reservoir Projects

Along the main conduit being constructed piecemeal as the spinal column of Israel's National Water Plan, of which the much publicised "Yarkon Negev 66" pipeline is a part, a chain of storage reservoirs are being built to collect flood and other water flows. In the main, the Plan is designed to bring surplus water from the north to the arid southerly Negev region and regulate water supplies all over Israel. Beginning in Upper Galilee where water is to be drawn from the Jordan River, the conduit will end in the Northern Negev and through it, by using electric pumping stations, millions of cubic metres annually will be fed to irrigation schemes and networks for the development of agriculture. Thus, efforts at present being invested in harnessing winter flood water from the Negev hills will, if successful, reduce the amount of water to be pumped from North to South. They are the building of dams and reservoirs in which flood water can be trapped, and drawn off after the rainy season for the agricultural use of man. This article tells of the progress already made in the building of such dams and reservoirs between Beersheba and Tel Yerucham.

"In the days of the Nabbateans, from 300 to 100 B.C., the Negev supported almost 100,000 people. They built dams and reservoirs, harnessed winter flood waters from the Negev and Hebron hills, terraced their hillsides to pervent soil erosion, and built a chain of cisterns and catchments. If they could do this successfully, with their limited knowledge and techniques, then the engineers of modern Israel must certainly be able to do much more." The speaker was not an archaelogist—although in truth it is one of his hobbies—but a young Jowish engineer from Ireland who is at present working in the Negev region. In fact his main preoccupation, which is buildings dams and reservoirs in the area, is rarely far removed from his hobby. Everywhere he goes, he sees evidence of man's successful struggle against nature, in the form of ruins surviving from Nabbatean and Byzantine times.

"Tolly" Brown's job is, in his own words, "to look after dam and reservoir construction, maintenance and performance, between Beersheba and Eilat", and because of this he spends four days of his week travelling between five dams. His tiny green Jeep, which seems to have been invented for just such a job, travels hundreds of miles in the process, and he handles it over tracks and desert sand, highways and stony hillsides like a toy. There are few nooks and crannies of the laige area he covers unknown to "Tolly" Brown, and in the four years he has been doing his job he has got to love the Negev landscape as few other men. At first, when one sees him wearing his Arab Kafiya (headscarf covering neck as well) one is tempted to dismiss this as an affectation, particularly as his blond hair, blue eyes, and face a bright red from the incessant sun, don't seem to fit the picture of the dusky Beduin of the desert. But it is in fact a genuine acclimatization, as is his knwledge of the region's history and problems, whilst his Hebrew scarcely betrays the soft, rhythmic tone of an Irish mother-tongue.

One of the problem, which after four years Tolly is only now beginning to master, is that his prominant nose is incessantly peeling. "Last year it began peeling in June, this year it started in August. Perhaps next year, the Negev will leave it alone". His home is in the new Afridar housing estate in Ashkalon, where he lives with his wife Rita—a trained social worker from Germany, and later England, where she spent the war years—and his six months' old daughter with whom he plays when not travelling. On Thursdays and Fridays he works at the "Tahal"[1] Headquarters in Jerusalem, to which the brings back progress reports of his dams and reservoirs.

Tolly's Five Dams

The first one, built near Hatzerim in 1950, was but a trial effort, consisting of a small side basin made to catch but 45,000 cubic metres of water. "We wanted to get experience of dam building with loess soil," said Tolly. Nowhere, it appears, have dams been built of this material but now he and his colleagues have gained knowledge through it of both the soil and the Negev climate. "The reservoir received water during three out of four years ; in the winter 1953/54 it filled to capacity and overflowed ; it proved that dams could be built with loess and remain stable ; undisturbed loess forming the bottom of reservoir is permeable ; and that a large runoff from a small wadi[2] basin will only occur after a cloudburst, which may take place but is an erratic happening in the Negev. Rainfall, if even 1" per day, will produce no runoff, but if 1" every two hours will certainly do so."

That had been the first dam and reservoir and Tolly and his colleagues had learned from it. When they began a second dam and reservoir in the same year, the design and structure were better. The site chosen on this occasion was indeed picturesque, for it was across the road from Negev village, kibbutz Shuval (one of eleven settled in 1946 which began Zionist colonization in the entire region), in the middle of the encampment of Israel's largest Beduin tribe. Although called the Tiyaha it has become known to every Israel citizen through the frequent publicity given to it as Sheikh Suleiman's tribe. The Sheikh, a colourful figure, has a streamlined Buick, thousands of camels, goats and sheep. There, surrounded by

[1] "Water Planning for Israel Company"—a semi Government agency responsible for carrying out the country's national water plan.

[2] A wadi is a stream bed, dry during most of the year and in winter carrying flood flows.

black, goat-skin tents, and loyal, dark-eyed tribesmen, buldozers and scrapers had begun scooping out the reservoir which was to hold 110,000 cubic metres of water.

Thu Shuval Dam, as it is called, was built eight metres high and had an outlet pipe for the use of its water. It was the cause of a virtual water festival during its first winter performance, for it filled and overflowed, the water going down its spillway. There was plenty for the tribesmen, who watered their livestock at the reservoir, as well as kibbutz Shuval which put it to use for irrigating its fields. In fact so encouraging were these first results that the Dam height was raised another two metres but, unhappily, the following year brought drought, and the reservoir was dry. The winter after that had also a modest rainfall and only 50,000 cubic metres of water entered the reservoir, but in the rainy season of 1954/55 it collected 200,000. In the meantime, according to Tolly, "the reservoir bottom sealed itself off after two years, became waterlight, and lost only 2 cms. daily through seepage and evaporation. It was noticed last year that the upper part of the reservoir leaked more than the lower, and now the engineers are considering treating the upper area to reduce percolation."

Dam Nahal Grar (Wadi Shariya)

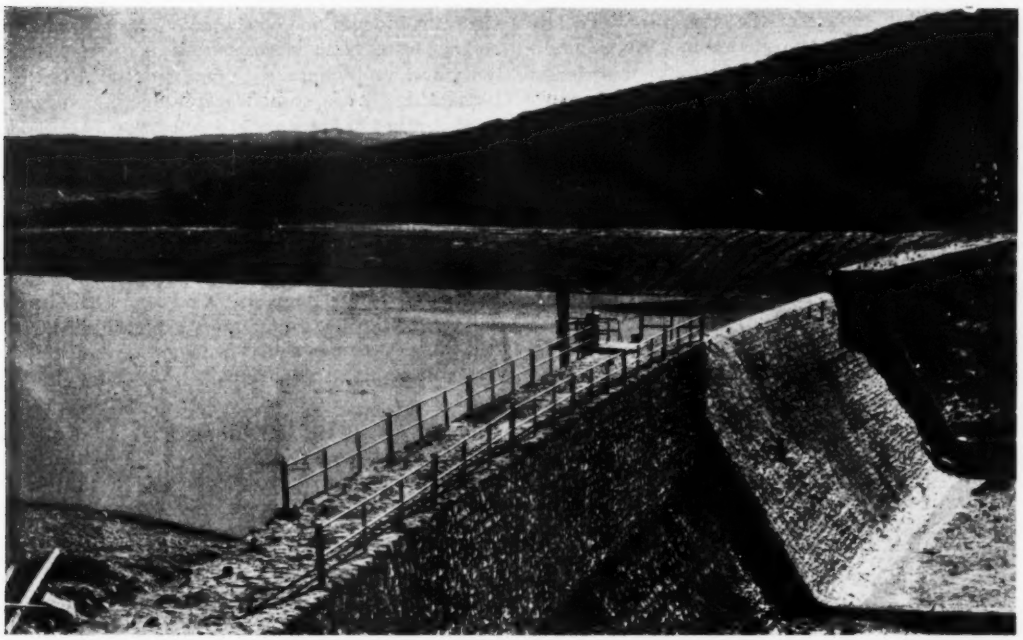
"Our largest earth dam, in fact the biggest experiment of its kind in the Negev today, is Nahal Grar near kibbutz Mishmar Hanegev. We built it to test the feasibility of reservoirs in chalk rock, with a height of 14 metres and a reservoir capacity of one million cubic metres", said Tolly. And here one could see where his engineering and archaeology found their happy combination.

Within sight of the huge dam, across the wadi amid lowlying sandy hills, were the ruins of an entire Byzantine water system. Along a shelf of chalk rock were the entrances to a series of huge cisterns, hewn out with the mark of ancient chisels chisels still showing on their walls, some as deep and long as a large sized hall. Nearby, intact graves lay open, bones which powdered to the touch. "Amazing how they know where to scoop out those cisterns, for one of the big problems of our reservoir here has been the amount of water lost through seepage into the rock".

The Nahal Grar Dam had also been built of loess soil, with a spillway quarried on one side of it to take overflow waters, and a large outlet pipe to channel them. Built in 1952-53, a drought year, only 100,000 cubic metres had entered the reservoir the following winter. This had seeped away rapidly at the rate of 10 cms. daily. The same thing had happened in the winter of 1954/55 when 200,000 cubic metres of water had been gathered; only this time the seepage rate rose to between 14 and 20 cms. each day.

And here, Tolly added a note of complaint. "Of course, as soon as this fact became known, people went around saying that the dam in unsuccessful. They are too used to getting quick results in Israel, and unused to the slower scientific method of trial and error. They will just have to be patient like every-

A Masonry Dam in Israel.



An Earth Dam in Israel.

where else, until we find the way to stop the seepage rate. We found one solution already at Tel Yerucham where the leaky area was covered by a layter of compacted clay, reducing seepage losses to negligible proportions. Other solutions are at an experimental stage, such as the spraying of the rock surface with cement mix."

On being questioned about the cause of seepage at this dam, Tolly had this to say : "All observation pipe in the rock showed that its natural water table—ordinarily 24 metres below the ground—had risen to 16, through the seepage of the reservoir water into it. This indicated that the success of a Negev reservoir depends upon the depth of the water table below the ground surface. Water table, by the way, simply means the average level of water stored in rock, based upon rainfall and impervious layer. If it is low, seepage will be high, as the rock has filled up. And since water only comes, into this wadi four times annually, no possibility exists of building up the water table for a long period. This is the fundamental problem of the northern Negev reservoirs. But, as I have mentioned in the case of Tel Yeruchan, there are solutions."

Tel Yeruchan Dam

Surrounded by low-lying Negev hills, gently peaked, duct-fawn in colour, with a belt of green vegetation indicating where the reservoir water had risen to its greatest height, the Tel Yeruchan Dam is in the Wadi Jiraffi, now named Wadi Yeruchan. Black streaks of flint rock shade the surrounding hillsides, and bull-dozers are working at the back of and above the dam laying a pipeline from it to the villages not far away. The reservoir itself is 110 metres long and 9 metres wide, has a capacity of 1,000,000 cubic metres of water, and was built in the winter of 1952-53. From the water, reaching up above the dam wall, is the cube-shaped tower in which is housed the instrument for recording the water level.

The first concrete dam to be built in Israel had, according to Tolly, the following history : Flood waters and its seepage rate was 20 cms. daily. This, to some extent, had been foreseen and when the rainy season had ended that year, work began in the laying of an impervious blanket of clay to reduce seepage in the reservoir bottom. In the winter of 1954-55 the rains brought 600,000 cubic metres of water and seepage losses had gone down to a maximum of 1 cm. daily and a minimum of 3 mms. In other words, the blanketing technique had been a success, suggesting that in other of the reservoirs where seepage is high, the same technique would meet the problem. As a result of the success of the Yerucham Dam, a pipeline was laid from it to the settlements Revivim and Mashavei Sadeh and, although this pipeline was completed too late for maximum water exploitation last winter, 100,000 cubic metres of water were passed on to the two settlements. Next year, this pipeline will enable the maximum use of collected flood water and besides being used for irrigation sources, the reservoir is also being employed as a carp-breeding pond..

Faluja

At present under construction, in the centre—although not a part of—the Lachish regional settlement concentration, is the small Faluja reservoir and dam with a capacity of 200,000 cubic metres of water. If successful, in other words if water-tight, this reservoir will pave the way for a huge reservoir to be one of the terminal points of the Jordan-Negev

(*Continued on page* 28)

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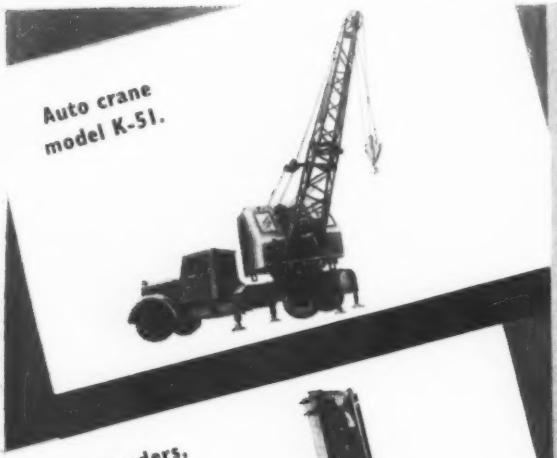

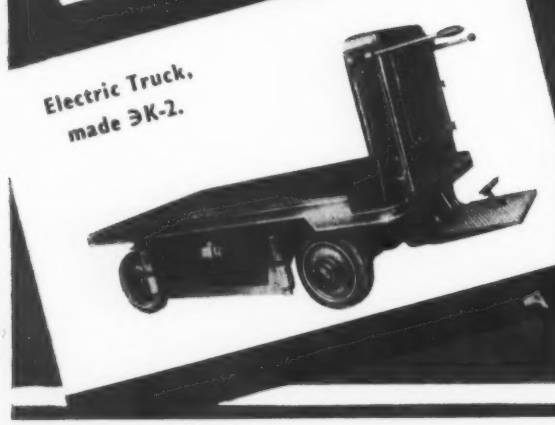

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Our Delhi Letter

(From our Special Correspondent)

The deluge that descended on the Punjab and Pepsu regions in the first ten days of October was a demonstration of that freak of nature which is witnessed only once in a century. The oldest of persons alive could not recall any occasion when so many centres of cropped lands and habitations were inundated in such measure.

Two-fold calamity

There was a two fold manifestation of the calamity. Torrents and rivulets swelled up into furious spate because of excessive run-off from upper catchments. And in the plains local precipitation was so heavy that pools and swamps assumed colossal proportions. The blocking up of natural drainages due to the presence of embankments of railways, canals and roads worsened the situation. The dislocation of communications added further tragedy to the crisis. Large areas of cropped land got submerged. Thousands of houses collapsed under the strain of continued precipitation to which was added submergence due to flooding. Not only crops were destroyed, but big areas of fertile lands got heavy deposits of sand, impairing their further productivity. All round the scene was one of unprecedented devastation, and thousands of people had to leave their hearths and homes and flee from the watery monster.

Definition of Objectives

This has called for fresh efforts from the Central and State Govts. who have made further demands on the engineer for working out a remedy. Two aspects of the problem stand forth. One is the definition of the scope of the problem. Second is the short range and long range measures, which can do real good. Under the influence of panic, there is danger of confusion of issues and of thought and much waste of public funds and efforts can take place.

Practical View

The conclusion is that total prevention of flooding can never be secured. Their effect can however be mitigated. Low places should not be selected for housing unless additional investment can be made for their protection from floods. And whenever any schemes and projects are made for embankments they should not be regarded as complete unless due provision is made for cross-drainage works with adequate water-way in the disposal of flood waters. It is short-sighted economy and professional dishonesty to ignore the expectable floods and to omit the provision of works which can deal with them effectively. It is a maxim that one can not have something for nothing. The same applied to flood protection works. Low embankments built without regard to their scientific efficiency are a mere eyewash. They generate a false sense of confidence. Complete remedy lies in storage reservoirs created by dams, detention dykes, and adequate bridging across the streams. The above can also serve only when due steps are taken for soil conservation and drainage. And these latter call for awareness about the problem in all spheres of planning and design.

Above all, there has to be a complete coordination and cooperation between contiguous units, whether they be districts or states or countries. This factor has been also realized lately and there are healthy talks of joint planning and collection of data between Nepal and India and India and Pakistan.

Board of Minister's meeting

The predominant feeling one gets from the deliberations of the Irrigation and Power Ministers of the States who assembled at the invitation of the Union Irrigation and Power Minister is about the great need for dissemenation of correct information. This is a rather neglected aspect as sufficient opportunities are not available in this country for the education of the lay-man about matters which are basically technical. The Ministers who are charged with the responsibility of good government and the creation of a Welfare State must understand the scope and extent of measures which are needed to safeguard the people against inroads and devastations that are caused by the vagaries of nature. It is only natural and correct that the specialization should not end with the engineers, but there should be the greatest desire on the part of Ministers and Parliamentarians to equip themselves with information, knowledge and the efficacy of various techniques. Only then will they visualise and accept the urgency of certain measures which are proposed by engineers. Also, in this way, they can become co-shares of the responsibility which devolves on both the technicians and the ministers. The remark is often heard, even in the ministerial circles, that there should be a college and refresher course for the education of Ministers.'

The Fruit of Seminars

In this third year of the Institution of Seminars we can now see how very effective it has been to cut across red-tape and achieve the stage of definite decisions in many complicated matters. At the early stages, criticism was often voiced that the Seminars are a mere debating platform and much good would not come out of them But that criticism has now given place to appreciation and commendation. In fact the State Governments and the top executives in the portfolios of Irrigation and Power derive inspiration from the Seminars Besides standardization of construction machinery and equipment, there is now a general desire to standardize in specifications and rates and this cannot but have a most healthy effect in the realization of the slogan "Build better, build cheaper."

All India Service of Irrigation and Power Engineers

The question of recreating the all-India Service of Engineers is now engaging the attention of the Govt

of India. There is however some resistance from the States, who feel happier if the engineers remain entirely under their direct control and the powers and privileges of distribution of patronage do not pass out of their hands. Prompted by this feeling, which is however not openly and frankly expressed they bring forth other reasons why the old ISE should not be created. But the needs of the country for an integrated outlook rising above State-boundaries are paramount and much strength has been added by the recommendations made in the S.R.C. report. The union Govt is however averse to putting any compelling pressure on the States in this respect and they are anxiously awating the emergence of of voluntary expression confirming the desirability of this necessary administrative reform. The tempo of the country's 2nd Five Year Plan demands that the Centre should have a force of an all India Service behind it so that it can plan formulate and supervise the execution of the chain of Projects which are necessary for the further development of the country. This subject will therefore need to be actively pursued in the agenda of the future Seminars.

Indian Industries Fair: New Records set up

A record crowd of 80 000 visitors was witnessed at the Industries Fair which was formally opened by Shri Jawahar Lal Nehru on October 29. Addressing the special gathering of 10 000 invitees in the shamiana in Hindi Pandit Nehru stressed the inevitable course of industrialzation, which India must follow in order to rise to her full stature. This being settled, India must have the "latest and the best" equipment. For this purpose self sufficiency in the heavy industries was essential. Hence those incharge of Industries must plan for the basis requisites of steel, heavy electrical plant and the machines which would make machines.

United Kingdom, USA, Russia, China, Germany and other countries are vying with each other in showing that they are all in a unique position for supplying the latest equipment to India. Co-existence in the political field presumes co-existence in the economic field and for this purpose the Indian Industries Fair has provided a unique opportunity to all the nations of the East and West for association in a cause of world peace and progress.

Bhakra and Hirakud stalls at the Industries Fair

These two stalls have been the centre of great interest for all the visitors particularly those from the country side. The Bhakra Dam is now entering a spectacular phase as the concreting operations are to start there in November and the Prime Minister is himself going to inaugurate the placing of concrete by pressing a button for the first bucket.

River Valley and the First and Second Five Year Plan

The time has come when we must assess how far we have achieved the targets set forth in the First Five Year Plan. In respect of the Bhakra Nangal and Hirakud Projects it can be stated that the targets reached are more or less according to schedule although there has been an over-all delay as compared with the targets which were given originally for these projects. But as Shri P. S. Rau recently indicated in his comment on the D.V.C. Projects, the earlier forecasts were more in the nature of guesses than firm commitments. In fact there never has been enough data on any project for firm estimates from where firm targets could be given either for costs or for time.

It can however be stated without any fear of contradiction that for the next 20 or 30 years the hands of Irrigation and Power engineers are going to remain fairly full. In fact according to a recent analysis made at Delhi by the Deputy Chairman, Planning Commission, it was stated that we can regard our targets to be still 50% short of what they will be, even if we make an all out effort to utilize our water resources. He estimated that we have still to give secure irrigation to 75 million acres of land besides what is contemplated in the First and Second Five Year Plan. On the side of hydro-electric power the picture is even more challenging because uptodate we have hardly developed more than 10% of the country's potential hydro electric power.

Power Engineering Research

The Government of India have set up a Committee consisting of the following members for a period of six months to formulate a programme for research work in respect of problems concerning power engineering development in the country for inclusion in the Second Five Year Plan :

Chairman

Prof. M. S. Thacker, Director, Council of Scientific & Industrial Research.

Members

Dr. K. S. Krishnan, Director, National Physical, Laboratory, Shri Yadava Mohan, Chief, Natural, Resources Division, Planning Commission, Shri S. A. Gadkary, Consultant, Planning Commission, Shri N. N. Iengar, The Tata Power Co. Ltd., Shri M. Hayath, Member, Central Water & Power Commission, Shri S. S. Kumar, Member, Central Water & Power Commission.

Secretary

Shri S. Rammohan, Officer on Special Duty, Central Water & Power Commission (Power Wing).

Central Construction Agency

The Government of India have appointed a Committee to work out the details of the scheme for the establishment of a National Construction Corporation. The Committee has been constituted in pursuance of the recommendations of the Third Engineers' Seminar held at Srinagar in July, 1955.

The Committee consists of the following :

(*Continued on page 28*)

Central Construction Organisation

With a large number of heavy construction projects in hand and with the prospect of many more to come with each succeeding year, the country has been facing the problem of having suitable construction agencies which could undertake these works for efficient execution. While some such agencies are growing—though only a very few in number—the tendency has been to undertake the execution departmentally. But the general experience of such a development in the country has been that such *ad hoc* expansion of a State department with the prospect of subsequent dismantling of the organisation is highly undersirable, not only from the economic point of view but also from the point of view of the best utilisation of experienced personnel and their team work, as also of the construction machinery. This is particularly so when, under planned development programmes, there seems to be no shortage of work in the immediately forseeable future. It is therefore encouraging to note that the question of having one or more central construction agencies in the country has been raised and already some constructive discussion on the subject has taken place. But the subject being of great importance, decisions on it should not be hustled through.

The Engineers Seminar held recently at Srinagar had placed this subject as one of the chief items for discussion. There were as many as five papers dealing with it, namely,

1. Need for a broad-based heavy Construction Industry—case for Construction Corporations by Dr. Sudhir Sen.
2. National Construction Companies for River Valley Projects by Sri B. P. Jain, Development and Planning Consultant.
3. An Indian National Company by Mr. H. L. Armstrong.
4. National Construction Corporation by Sri Kanwar Sain, Chairman, CW & PC.
5. Methods of Construction of River Valley Projects in U.S.S.R. by Sri. Kanwar Sain.

Subsequently the matter was taken up in the Coordination Board of Ministers for Irrigation and Power of different States and it was decided to set up a strong committee with Mr. T. Sivasankar, Secretary, Ministry of Irrigation and Power, Government of India, as Chairman, to work out the details of the scheme for the establishment of a National Construction Corporation.

The various questions referred to this Committee are :

(*a*) Whether there are any difficulties in the way of setting up of the organisation and how these difficulties can be overcome.
(*b*) Whether the organisation should be a statutory Corporation or a company under the Indian Companies Act.
(*c*) Whether the capital should be subscribed by the Centre only or by the Centre and the States which agreed to utilize the organisation for construction work, or shares should be open to the public.
(*d*) The approximate amount of capital for the organisation.
(*e*) Whether business representatives be included in the management.
(*f*) The strength of the Board of Directors and who should nominate the Chairman and the the Managing Director.
(*g*) Scope of the Corporations duties and functions.

From a study of the brief summary report of the discussions held at the Engineers' Seminar, it becomes perfectly clear that while there was a general consensus of opinion about the establishment of a national construction corporation, there was an equally emphatic consensus of opninion that in establishing such an organisation the element of competition in construction work should be maintained in order to assure fair cost and quality in work. Dr. Sen's paper was clear on this point. Mr. S. N. Kapur, Mr. M. R. Chopra, Mr. A. C. Mitra and Mr. Kanwar Sain—all these leading engineers wanted such a Corporation to work as a contractor without any special privileges.

Again, in an enlarged *ad hoc* Sub Committee to consider the question the issue was posed explicitly thus :

"Will it work as an ordinary contractor or have any special privileges ? If so, what ? Will it have any monopoly ? If not, how will fair competition be ensured ?"

And the Sub Committee came to the following clear conclusions :

"The Corporation will function as an ordinary contractor and will compete with other contractors, corporate bodies or individuals on equal terms."

Has this viewpoint been accepted by the Government ? But the press report of the speech of the Minister for Irrigation and Power before the Coordination Board gives a different impression. The Committee now set up to go into the details of the proposal

has not either been specifically charged to consider the issue. We consider that this is one of the crucial issues for the consideration of the Committee. As the summary of Mr. Kanwar Sain's paper on the situation in the U.S.S.R. indicates, it is not possible to find out whether the constructing agency in that country is performing its functions economically or efficiently as the element of competition is completely absent. We do not think that we should or need have such a structure for a State-sponsored construction agency in our country.

The issues involved in this question have a wider implication and it would be in the fitness of things if the matter is discussed more widely than is being done at present, before a firm decision is arrived at.

(*Continued from page 24*)

Problems of Israel's Reservoir Projects

conduit, storing 25 million cubic metres of water. In the area is a large layer of clay of varying thickness, from which huge mechanical scrapers incessently scoop their loads and deposit them as a flooring over the sandy bottom of the reservoir. As they do so, the clay is sprayed and softened by hosed water, and then broken into bits and compressed by heavy Sheepsfoot rollers. "The water table is 20 metres down, and we are watching whether the clay reservoir, bottom will prevent seepage", says Tolly.

Working at top speed, the huge procession of machines make their endless circle around the reservoir, scoop earth from the hillside, and are followed by the rollers, pounding and pressing it tightly. The shape of the dam becomes outlined by its packed earthside, covered over by its layers of stone, brought and dumped on it by large tipper-tracks. Engineers, workers and on-lookers watch its progress anxiously, for so much is at stake. In the meantime, the roar of machines, and the clouds of dust, make the scene reminiscent—in this otherwise barren piece of territory—of a scene out of an H.G. Wells forecast of the future.

There will be more

The five Negev dams are only part—although the first and because of their experimental nature, the most important part—of Israel's plan to catch what is estimated by some as 33 million cubic metres of flood water which pours down the hills Hebron and the Negev at tremendous speed and for a short period almost each year. So far, some IL 20 millions have been spent on them out of the country's development budget, and they have employed many people in their construction.

Dam Six, the plans for which have already been drawn up, is to be that of Nahal Zin, placed near the Potash works at the Dead Sea. The works are in constant danger of winter flooding, when water from heavy rains rushes along the wadi Zin, running from historic Abde past Sdeh Boker and into the Dead Sea. This large dam, supported by a number of smaller ones along the Wadi, is to intereept this rushing water, and its reservoir is planned to store as much as 10 million cubic metres of water. "All of the dams", stresses Tolly, "are placed where the National Water Plan requires large storage reservoirs."

The Negev is coming to life

People like Tolly Brown, 28 year old Dublin engineer settled in Israel, are bringing the Negev region back to life, after its centuries of bleak desolation and uselessness. They are little known, except by their immediate colleagues, for they seek no limelight nor publicity, but quietly and efficiently get on with the job which is nothing less than building a country. Following the footsteps of the ancient Nabbateans, but with engineering knowledge and technique of modern quality, and with the use of huge machines and the backing of a modern State, Tolly—like them—has good cause of say : "Winter Floods Be Dammed".

(*Continued from page 26*)

Our Delhi Letter

Chairman

Shri T. Sivasankar, ICS, Secretary, Ministry of Irrigation & Power.

Members

Shri Yadava Mohan, ISE, Chief of Natural Resources Division, Shri S. Ratnam, Joint Secretary, Ministry of Finance, Shri K. N. Subramaniam, Joint Secretary, Planning Commission, Shri S. N. Lokur, Joint Secretary, Ministry of Law, Shri L. P. Bhargava, ISE, Member, Central Water & Power Commission, Shri P. C. Suri, Director, Public Management Study Section, Planning Commission, Shri E. Kolet, Deputy Secretary (Financial Adviser), Ministry of Irrigation & Power.

Secretary

Shri S. Venkataraman, Deputy, Secretary, Ministry of Irrigation & Power.

The Committee will report on (a) whether there are any difficulties in the way of setting up the organization and how these difficulties can be overcome ; (b) whether the organization should be a statutory corporation set up under an Act of Parliament or a company under the Indian Companies Act ; (c) whether the capital should be subscribed by the Centre only or by the Centre and the States which agreed to utilize the organization for construction work, or shares should be open to the public; (d) the approximate amount of capital of the organization ; (e) whether business representatives be included in the management ; (f) the strength of the board of directors and who should nominate the chairman and managing director ; and (g) scope of the corporation's duties and functions.

Book Review

Irrigation and Hydraulic Design, Vol. I, : General Principles of Hydraulic Design, by Serge Leviavsky, Ph.D., M.I.C.E., M.Am. Soc. C.E., Chapman and Hall Ltd, 37 Essex street, London, W.C.2, 10″×7,″ 512 pages, 126 sh/-.

This book, which forms the first of a three volume set on the general principles of irrigation and hydraulic design, will, after the compilation of the remaining two volumes, become a classic on the subject and an 'opus magnum' in the field of hydraulic engineering. This peculiarly singular feature principally stems from the erudite scholarship of the author and his vast experience stretching from Egypt to Russia. As a former Director, Designing Service, Reservoirs and Nile Barrages Department, Ministry of Public Works, Cairo ; Chief of Designing Office, Irrigation Projects Department, Cairo ; Professor of Irrigation Design, Royal School of Engineering Design, Guiza ; and Head of the Hydraulic Section of Lock and Dam Construction Works on the Dnieper Falls, Russia ; Dr. Leliavsky's technical life is probably unique in the annals of modern irrigation engineering.

The work of the author has spanned literally two periods in the study of hydraulic engineering, transgressing the older accepted canons of thought in that field, into the modern concepts, completely overthrowing the previous theories and methods. In 1925 work was undertaken on the percepts formulated by Bligh, Morley Parker, Forchheimer, Kiishi Hayachi Engels and Francius, while after just ten years, a complete revolution took place in the general methods mainly due to the teachings of such authorities like Terzaghi, Pavlovsky, Lane, Boris Bakhmeteff, Khosla, and other prominent engineers of the generation. Even after that, the theories of turbulence brought out through the pioneering investigations in the aeronautical engineering field by Karman and Prandtl, and generally released through the publications of Professor Bakhmeteff and Professor Rouse, have still further altered the modern conceptions in hydraulic engineering and paved the way ahead. The author rightly considers that the principles of modern design cannot be fully understood without a basic knowledge of these new ideas and of the theoretical fundamentals governing them.

The first volume under review contains the more general fundamentals of design work, especially concerning percolation in the granular foundations beneath hydraulic structures and in earthen banks, tail erosion in its various aspects, and uniform and non-uniform hydraulic flow in rivers and canals. The difficulties of constructing structures of large magnitude on a permeable bed are common to engineers in both Egypt as well as India, and the author's coverage of this topic is quite lucid and impressive. The overall picture presented here is in the reviewer's opinion well worth a detailed study by all designers in this country. In dealing with the specific foundation problems, the author brings out the well known Khosla's theory, in discussing the strength of sheet piling, and shows that a single line of sheet piling is capable of withstanding for a short time a far greater head than could ever be explained by Bligh's line of creep method. The mechanical theory of seepage which has resulted in the publication of numerous investigations, are discussed in their correct light and are critically examined, while Professor Lane's approach to the solution of percolation problems is also surveyed, noting the fact that he has examined as many as 278 dams and weirs of different descriptions built on various soils. The results of model analysis are also brought out and given their due share of merit. The last section covers the hydraulics of canals and rivers, beginning with a brief historical introduction. In dealing with pipes, the author has surveyed a variety of investigations and results obtained by different authorities in arriving at a correct value of the rugosity factor, for various types of materials of pipes and the finish. The reviewer failed to notice any mention of the value of rugosity for aluminium alloy pipes, especially in view of the fact that these light alloys are now being increasingly used for irrigation and in carrying petroleum and other fluids. In fact data on this particular subject is not easily available in any standard text and the inclusion of such information would have considerably enhanced this section. The question of the correct significance of the 'hydraulic radius', has attracted the attention of many hydraulic designers, and as such the author has taken up this point for discussion. The rather elementary approach of the original Chezy theory, cannot be taken, according to the author, in the light of the modern mechanical analysis, as substantiating theoretically the use of this factor, and additional evidence has gradually accumulated showing loopholes in its deductions. The remaining part of this chapter covers steady non-uniform flow and backwater wave analysis. In this section some nine different methods of solution are presented, which according to Dr Leliavsky, will soon develop into an outstanding branch of irrigation-design theory, tending to convert some of its old-fashioned, conventional standards into rational solutions.

Within the standards set forth and the tentative contents enumarated for the remaining two volumes, it appears that the author has not covered the field of movement of solid material in water; and problems involved in the rise of water table due to irrigation and the consequent evaporation. The former arises in silting of reservoirs and barrages, and silt exclusion problems of canals, while latter, as many engineers are aware here, form a menace in canal systems of the

Punjab. According to the author, the second volume will contain specific design methods and theory for irrigation works ; including regulators of all sizes and descriptions from the smallest canal inlet to a Nile Barrage ; syphons, weirs and other canal structures ; planning and designing a perennial irrigation scheme ; and irrigation-canal bridges, and aqueducts. The third volume is intended to cover multiple-purpose hydraulic structures, such as the various types of headwaters on alluvial rivers, from the standpoints of design, economics ; the electrification of existing headworks and hydraulic power stations in general ; and navigation locks, arches and dams.

The accumulated stock of irrigation literature in the field of hydraulic theory and design is already large and for any new text to claim any merit would necessitate the formulation of rational concepts and the presentation of facts and figures in a perfectly logical fashion. That this publication fully lives up to these attributes and sets a new pace in the field of hydraulic literature assures it, and the forthcoming volumes, a very valued place in the domain of irrigation and hydraulic engineering. Printed, set, and presented in a faultless fashion, the only drawback of the text is that its price is beyond the purse of the average engineer, although looking to its mammoth contents it cannot be considered very high.

S. K. GHASWALA

Billings and Water Power : by Adolph J. Ackerman, American Soc. of Civil Engineers, 33 West 39th street, New York 18, N.Y., USA, 142 pages, $ 7.00.

The story of hydro-electric engineering and power development in Brazil from 1925 to 1950 is essentially the story of the contributions made by an American engineer, Asa White Kenney Billings, one of the world's foremost hydro-electric engineers. So begins the Prologue of the first chapter of this text, which actually forms the farewell address presented by Ackerman, President, Brazil Section of the American Society of Civil Engineers, in Sao Paulo, Brazil, on August 7, 1951. While men like Henry Ford, Andrew Mellon, and John D. Rockefeller have adorned the pages of American industry, and given that nation greatness, Billings contributed enormously to the development of Brazil's hydel development and thereby to that country's economic prosperity. Although he is best known for his work in Brazil, Billings had previously attained prominence in the engineering profession through his work in Spain, on two of the world's highest dams, as well as through his reputation as a consulting engineer on hydro-electric projects in the United States, Cuba and Mexico.

The principal achievements of Billings can be summed up by the progress made from 1922 to 1945, when a total of 15 generators and pumps were installed with a combined rating of 690,000 h.p. During the six-year post war period beginning in 1946, when Billings relinquished active direction of the hydro-electric program, a total of 9 additional generators and pumps were installed, having a combined rating of 527,000 h.p. ; and a further 21 generators and pumps were purchased with an aggregate total rating exceeding a million h.p. for installation during the period of 1951 to 1955.

The 12 chapters of this text principally cover the activities of this savant from his school days right upto his death in 1949, during which period he contributed greatly to the hydro-electric profession. The work is lucidly woven round this great personality and intimately reveals the hydel developments of the times and an insight into the social conditions. Brazil offers an unsually singular challenge to the development of hydro-electric power mainly through its topography. For a stretch of nearly 1300 miles the southern coast of the country, north of Uruguay is marked by a low coast line, in the rear of which there rises a very steep escarpment leading on to a rich and fertile plateau some 1000 to 2000 feet above sea level. This plateau, well known as "The Serra", was ascended only by a handful of men in the earlier days, and as such not much was known about the land. The main drainage of this interior region is not towards the coast but inland westwards through the various tributaries to the Parana river which roughly paralleling the coast runs inland some 300 miles, and finally reached the Atlantic in the Rio de la Plata at the Buenos Aires. Here there are inland streams, which could be directed over the steep escarpment of The Serra, and developed under a head of a thousand feet or more. The development of these power projects are covered in the succeeding chapters on Brazil, Rio de Janeiro, Sao Paulo, including the various structures built there.

Billings was a man of vision and had confidence in his work and undertakings. He initiated hydrological and meteorological studies while he was among the first to employ agronomists to study the best suited marine plants and fishes to inhibit the lakes inorder to maintain clean water. The tributes he received from that grateful nation are succinctly brought out by the author in the last two chapters of this well presented account of the work and life of Billings. At the right time, the right man came to the right place to apply his genius in helping to lay the foundations for the industrialization of a greater Brazil. His story is worth reading.

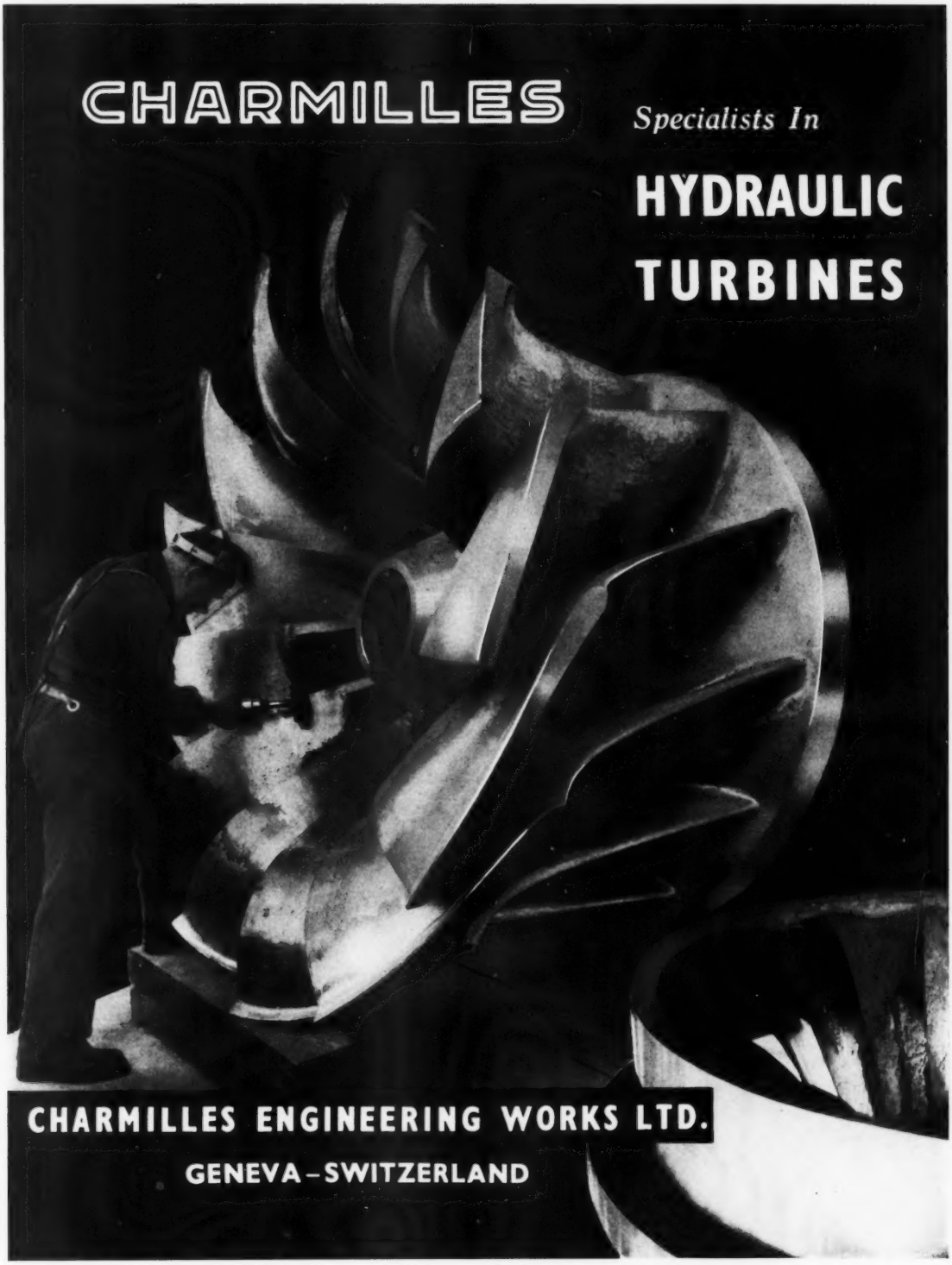
(*Continued from page 21*)

Role of Forests in Flood Control Bhakra Nangal Project

hydraulic engineer, H. G. Morgan, had remarked that "If we could raise the underground water table of Tennesee Valley only six inches, that would mean twenty six million acre feet of water—four times as much as the Norris Reservoir will hold."

It will, therefore, be worthwhile spending the amount spread over a number of years on the flood control and Soil Conservation measures.

(*By Courtesy of the Indian Forester*)



Runner of one of the TUNGABHADRA turbines

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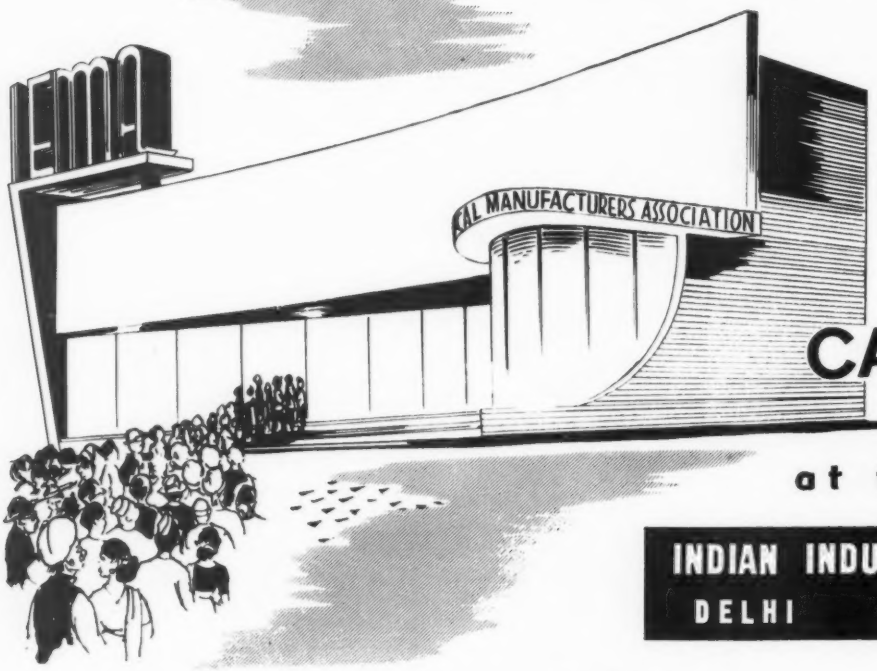

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